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Impacts of Glyphosate Application on Grizzly Bear Forage Production in the Coastal Western Hemlock Zone

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Impacts of Glyphosate Application on Grizzly Bear Forage Production in the Coastal Western Hemlock Zone

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ABSTRACT

The impacts of glyphosate on grizzly bear forage availability in coastal British Columbia were investigated. Emphasis was on floodplain ecosystems. Impacts were examined at three scales: 1) regional—occupied grizzly bear habitat in the Coastal Western Hemlock (CWH) zone; 2) local—one watershed representative of operational use; and 3) site-specific—plots in 22 cutblocks. Changes in percent cover and fruit production of bear forage species were monitored following foliar and individual stem treatments. A simple efficacy trial was also conducted. Information from the Pesticide Control Branch shows that an average of 1826 ha per year has been treated with glyphosate in occupied grizzly bear habitat in the CWH zone since 1986. Habitat mapping in the Chuckwalla–Kilbella watershed indicated that most glyphosate is used on areas of medium and high value bear forage. Foliar application, particularly by backpack or powerhose, influenced the amount of forage available for at least 3 years after treatment. Total cover of fruit-producing shrubs declined an average of 63% 1 year after operational foliar treatments. Recommendations for the integrated management of grizzly bears and forestry-related glyphosate use include: 1) using the biogeoclimatic ecosystem classification system to structure integrated management prescriptions; 2) assessing proposed treatments in the context of habitat supply within the watershed; 3) using application rates no higher than required to meet silvicultural obligations; 4) avoiding bear forage species not directly competing with crop trees; and 5) assessing alternative silvicultural methods. Integrated resource planning on floodplain site associations should consider the likelihood of silvicultural success, the economics of harvest and reforestation, and bear habitat values over time.

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1 INTRODUCTION

The rich, moist, alluvial floodplains and lower slope fans in the Coastal Western Hemlock (CWH) biogeoclimatic zone of mainland coastal British Columbia are among the most productive conifer-growing sites in the province. The same area also supports some of the highest densities of grizzly bears (*Ursus arctos*) in Canada. Increased emphasis on the reforestation of these sites is in direct conflict with the maintenance of grizzly bear forage values after logging.

The CWH zone is the object of increasingly intensive forest management, including expanded reforestation efforts. However, attempts to re-establish free-growing conifers on floodplains have been generally unsuccessful largely due to severe competition from shrubs and deciduous trees. The application of herbicides—particularly glyphosate—is among several methods undertaken to reduce this competition. Glyphosate has become one of the most frequently used herbicides in British Columbia since its registration for forestry purposes in 1984 (Biggs and Walmsley 1988; Ackurst 1989). It can be used as a foliar treatment to reduce brush competition in young conifer plantations, or as an individual stem treatment (hack-and-squirt) to release conifers in stands dominated by young deciduous trees. It is widely accepted as a means of achieving "free-to-grow" status in compliance with Section 129.3 of the Forest Act and as a tool in the rehabilitation of unsatisfactorily restocked sites.

A study in the Kimsquit, a mid-coast watershed, showed that grizzly bears spend at least 60% of their active period in floodplain and low elevation fan habitats (Hamilton 1987). Evidence collected on the south coast (Lloyd 1979; Leigh-Spencer[1]) also indicated heavy use of floodplains. Preliminary results of a study in the Khutzeymateen watershed, north of Prince Rupert, suggest that valley bottom habitats may be even more heavily used in the wetter subzones of the CWH (Nagy and MacHutchon 1991).

Grizzly bears will feed on a variety of shrub fruit and herbaceous forage in clearcuts, beginning about 2 years after logging. They are often seen foraging in recent clearcuts between late June and early September, and bear sign is common along logging roads. In the Kimsquit, two intensively monitored females spent approximately 2% of their active seasons in recently logged areas (Hamilton *et al.* 1986). Observations from other watersheds indicate this percentage may be higher elsewhere on the coast (A. Hamilton, unpublished data, 1990, B.C. Ministry of Environment, Victoria, B.C.).

Hamilton (1987) also concluded that floodplain and fan deciduous forests (natural or post-logging in origin) are extremely important bedding and feeding habitats, accounting for 38% of active season use by grizzly bears. The younger stands of these deciduous types are potential candidates for conversion to conifer plantations, beginning with individual stem treatments.

In a preliminary survey in the Kimsquit, a cutblock treated with glyphosate in August 1985 showed a significant reduction in both shrub fruit productivity and bear use. Few red elderberry (*Sambucus racemosa*) or salmonberry (*Rubus spectabilis*) plants survived. Those that did were top-killed or malformed, and 60% of the malformed stems marked in 1986 were dead by 1987. Fruit production dropped and there was a noticeable decrease in cutblock use by radio-collared bears in 1986. Follow-up surveys in 1987 indicated a partial recovery of fruit production, but there was an apparent shift in species composition. Fruit production further recovered in 1988 and 1989 and at least one grizzly was feeding on fruit during 1989. However, the site is once again scheduled for treatment.

Of the 16 fruit-producing shrub species fed on by coastal grizzly bears, 10 are potential competitors with conifer seedlings and are, therefore, potential "targets" in herbicide programs (Haeussler and Coates 1986). Three of the most important bear forage species—salmonberry, red elderberry, and black twinberry (*Lonicera involucrata*)—are severely affected by glyphosate (Balfour 1989). A fourth important species, red raspberry (*Rubus idaeus*), may be severely affected but appears to be an "increaser" 1–2 years following herbicide treatment (J. Pollack, pers. comm., cited in Balfour 1989).

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[1] Leigh-Spencer, S. 1978. Machmell-Genessee grizzly study: summary of the behaviour and seasonal distribution of grizzly bears of coastal B.C. and the implications on development of the Machmell flats. Unpublished report submitted to B.C. Forest Products Ltd., Crofton, B.C. 11 p.

Several projects are studying reforestation of floodplains in the CWH including: examinations of herbicide efficacy versus mechanical and manual alternatives[2,3]; an evaluation of alternative silvicultural systems[4]; a study of the relationship of hydrology to silviculture investment (Beaudry 1988); and the development of ecosystem-specific interpretations (D. McLennan, pers. comm., Feb. 1990). However, none of these projects directly address wildlife concerns.

A problem analysis by Biggs and Walmsley (1988) showed that there was "a complete lack of research on the impact of herbicides on the habitat and food resources of grizzly bear, black bear, raptorial birds, upland game birds." Research on the impacts of herbicides on grizzly bears was ranked second by the same authors "because of the high degree of management concern for the species, and because of the anticipated increase in herbicide use in the CWH primarily for salmonberry control."

A major study of the impacts of glyphosate application on grizzly bear forage production in the CWH was first proposed in 1986. Funding was granted in late 1987 under the Extension, Demonstration, Research and Development Sub-Program of FRDA for the final 2 years of the agreement.

1.1 Objectives

This study was designed to collect information on the impact of glyphosate on grizzly bear forage, and to develop management recommendations for the integration of grizzly bear habitat requirements and silviculture on rich alluvial and lower slope sites in mainland coastal British Columbia.

Specifically the objectives were:

1. to investigate the impacts of glyphosate application on grizzly bear forage species composition, cover, and fruit production in logged floodplain alluvial and lower slope ecosystems in the CWH zone;
2. to determine the severity and geographic extent of these impacts on grizzly bear habitat capability; and
3. to contribute to the development of integrated grizzly bear habitat management and silvicultural prescriptions.

1.2 Study Areas

Study area selection was based on information from Pesticide Use Permits on file with the Pesticide Control Branch, Ministry of Environment, and on discussions with regional habitat protection biologists. Areas selected had 1988 glyphosate treatments proposed for floodplain or lower slope sites in the mainland CWH (Figure 1). The variety of treatment methods, availability of pre-1988 treatments, and bear value of the watershed were also considered. General ecological and administrative characteristics for these sites are presented in Table 1.

2 METHODS

2.1 Field Data Collection

To ensure the broadest possible application of results, data were collected for 1988 operational treatments (pre- and 1-year post-treatment with controls), and 1984–1987 operational treatments (post-treatment, no controls). Treatment types included hack-and-squirt and foliar (aerial and backpack/powerhose). Sample sites were chosen on the basis of glyphosate treatment plans, site history, site characteristics (floodplain or fan), seral stage, and forage cover.

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[2] D'Anjou, B. 1989. Growth response of vegetation to chemical and manual cutting treatments in the Vancouver Forest Region. B.C. Min. For., Victoria, B.C. FRDA Project 2.35. Draft manuscript.

[3] Coates, D., P. LePage, and J. Pollack. 1990. The conversion of multistoried brush fields to coniferous plantations: a benchmark evaluation of alternative silvicultural treatments. Treatment effects on competing vegetation and conifer growth. B.C. Min. For., Victoria, B.C. FRDA Project 2.6. Unpublished manuscript.

[4] Standish, J.T. 1990. Alternative silvicultural systems for streamside management zones and steep slopes in coastal British Columbia: recommendations based on an opinion survey and field observations. SMFRA 3.0. Prepared for the B.C. Min. For., Burnaby, B.C. Unpublished manuscript.

FIGURE 1. Location of study areas: 1. Chuckwalla and Kilbella rivers (Rivers Inlet); 2. Kingcome River (Kingcome Inlet); 3. Klinaklini River (Knight Inlet); 4. Phillips River (Phillips Arm).

TABLE 1. General ecological and administrative characteristics of study areas

Study area	BEC variant	EC[a]	Tenure	Licensee	Ministry of Environment Region	Ministry of Forests Region	Ministry of Forests District
Chuckwalla	CWHvm1	NPR	FL A16847	CPFP	5	Vancouver	Mid Coast
Kilbella	CWHvm1	NPR	FL A16847	CPFP	5	Vancouver	Mid Coast
Kingcome	CWHvm1	NPR	FL A19328	Interfor	1	Vancouver	Port McNeill
Klinaklini	CWHms2	NPR	TFL 17	Fletcher Challenge	1	Vancouver	Campbell River
Phillips	CWHvm1	NPR	TFL 39	MacMillan Bloedel	2	Vancouver	Sunshine Coast

[a] Ecoregion classification – NPR = North Pacific Ranges Ecosection (Demarchi 1988).

For each cutblock ("block") selected, permanent 5 x 5 m "macroplots" were established at intervals of 25–110 m along a transect. Macroplots, two to six per block, were located to characterize typical site conditions.

Soil and site data were collected at each macroplot in 1988 as per Walmsley *et al.* (1980). Soil horizons, depth, texture, humus form and special features (e.g., mottling, depth to water table) were noted and soil profiles classified according to the Canadian system of soil classification (Agriculture Canada Expert Committee on Soil Survey 1987). Site information included slope position, percent slope, aspect, ecological moisture and nutrient regimes, and seral stage.

Vegetation data were collected at each macroplot in 1988 and again in 1989. Data recorded for each fruit-bearing shrub species included percent cover, vigour, distribution and phenology (vegetative and generative). Percent cover of all vascular plant species in each of four strata were estimated. An index of fruit abundance was calculated from estimates of percent stems bearing fruit and average berry abundance (Hamilton 1987). If ripe fruit was present in the macroplot, then all fruit was picked and weighed. A salmonberry shrub that was severely affected following a 1987 aerial treatment was flagged in 1988 and examined for signs of recovery in 1989.

One metre square "microplots" were located at each inside corner of a macroplot. A plastic frame was used to outline microplot area. A complete list of vascular plants, including overhanging trees, shrubs and herbs, was made for each microplot in 1988 and again in 1989. Percent cover, distribution, vigour and phenology were recorded for each species present and conifer seedling heights were noted. Percent cover estimates of slash, rotten wood, stumps and mineral soil were made in 1988. Nomenclature of plant species followed Taylor and MacBryde (1977) and Meidinger (1987).

A simple glyphosate efficacy trial was conducted in co-operation with Fletcher Challenge Canada Ltd. in the Klinaklini River valley. Three application rates were used: 1.42 kg a.i./ha, 0.71 kg a.i./ha, and 0.36 kg a.i./ha. Spraying was done by helicopter in mid-August 1988. There were three macroplots in each treatment; four macroplots were established as controls. The total area sprayed was 2.25 ha. Several stems from highbush-cranberry (*Viburnum edule*) and salmonberry were flagged in 1988 and examined for herbicide damage in 1989.

Percent cover of each fruit-bearing shrub species known to be grizzly bear forage (Appendix 1) was the principal variable analyzed for the different treatment types. Mean percent cover of these "forage shrubs" was calculated in two ways: 1) percent cover for each macroplot averaged over all macroplots in the block ("macrocover"); and 2) percent cover from the microplots averaged for each macroplot and then averaged over all macroplots in the block ("microcover"). Percent cover of species other than forage shrubs (microcover only) and strata cover (from macroplots) were also considered in the analyses.

Two-way Kruskal-Wallis tests were used to look for significant differences ($p \leq 0.10$) in total percent cover of forage shrubs among 1988 and 1989 data from treated blocks and controls ($k=4$). The null hypothesis was that there would be no differences among years, treatments and controls. For each treatment type (e.g., 1987 foliar) there were three sets of tests: all forage shrubs grouped together, Group "A" forage shrubs, and Group "B" forage shrubs. Groups reflected differences in susceptibility to herbicide damage (Balfour 1989; D'Anjou[5]). Group A was black twinberry, salmonberry, red raspberry, thimbleberry (*Rubus parviflorus*), and red elderberry. Group B was red-osier dogwood (*Cornus sericea*), stink currant (*Ribes bracteosum*), trailing black currant (*Ribes laxiflorum*), black raspberry (*Rubus leucodermis*), highbush-cranberry, devil's club (*Oplopanax horridus*), and *Vaccinium* spp. Devil's club, although a major bear food species in forested habitats, was omitted from Group B analyses for blocks treated with foliar spray because it is neither a competitor with conifers nor a food source in shrub-dominated cutblocks.

2.2 Watershed Habitat Mapping

Grizzly bear habitats were mapped in the Chuckwalla–Kilbella watershed as a means of assessing the impacts of glyphosate on habitat values at the watershed level. A simple classification was developed (Table 2). Habitat units and successional stages (described in Appendix 2) are similar to the Bear Habitat Units and successional stages used in the Kimsquit (Hamilton 1987).

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[5] D'Anjou, 1989.

Habitat polygons were identified on 1987 1:10 000 colour airphotos after initial ground reconnaissance. Mapping was confined to the river bottom and lower slopes because of limited airphoto coverage and distribution of logging. Polygons were delineated on the basis of site conditions, successional stage and site history. They were then transferred to 1:50 000 base maps and labelled. Percentiles were used to indicate relative proportions of habitat units/successional stages ("habitat types") in complex polygons. Habitat types were given a "bear value rating" (high, medium, low or nil) (Appendix 3) for each of five seasons (Table 3). Two ratings were assigned to glyphosate-treated habitat types: one with the impacts on bear forage considered, and another as though no treatment had occurred. The impacts of glyphosate were projected for 3 years post-treatment only. The area of each habitat type was then determined, and the areas were totalled by bear value rating — first, with actual 1986–89 glyphosate treatments, and second, as if these had not occurred. Maps were digitized with PAMAP GIS (PAMAP Technologies Corporation, Victoria, B.C.) and area summaries were generated using the GIS and dBase III Plus (Ashton-Tate Ltd., Torrance, California).

TABLE 2. Grizzly bear habitat classification for Chuckwalla-Kilbella watershed

Habitat units	Successional stages (within habitat units)
AV Avalanche chute	1 Non-vegetated
CS Cedar Seepage Forest	2 Herb/shrub <10 years (older if not treed)
ES Estuary	3 Pole sapling 10–40 years
FF Floodplain/fan	3D – deciduous
HB Hemlock-Blueberry Forest	3C – coniferous
HM Hemlock-Moss Forest	4 Young forest 40–80 years
RO Rock Outcrop	4D – deciduous
RT Rock/Talus (high elevation barren)	4C – coniferous
SF Subalpine (forested/parkland complex)	5 Mature forest 80–250 years
WE Wetland	6 Old-growth forest >250 years

TABLE 3. Seasons of coastal grizzly bear activity (Weaver *et al.* 1986)

Season	Start	Definition
1	Early April	Den emergence to valley floor leaf flush to avalanche chute green-up
2	Late May	Avalanche chute green-up to berry availability (includes use of estuary)
3	Late June	Berry availability to salmon availability
4	Late August	Salmon availability to den entrance
5	Early November	Denning

2.3 Forestry-related Glyphosate Use in the CWH

Computer files obtained from the Pesticide Control Branch were summarized to determine the level of glyphosate use in occupied grizzly bear habitat in the CWH. Summaries may also include a limited area within the Mountain Hemlock (MH) Zone. The two zones could not be easily separated using the information available. The computer files have information from Pesticide Use Permits, with start dates back to 1985. Follow-up data (area treated annually) was current to the end of 1988. The initial computer extract was shortened by eliminating those permits 1) outside the CWH; 2) intended for purposes other than operational silviculture (e.g., research trials and right-of-way treatments); and 3) intended for chemicals other than glyphosate. The remaining permits were then classed as being in or outside occupied grizzly bear habitat. Additional information on glyphosate use in the CWH was obtained from reports prepared by the Protection Branch of the Ministry of Forests.

3 RESULTS

3.1 Field Data Collection

3.1.1 Herbicide Impacts

In 1988, field work was carried out between June 27 and July 31. Seventy-six macroplots were sampled in 22 blocks (11 blocks treated in 1988, 10 blocks treated 1984–87, 1 control block). Site history information for the sampled blocks is in Appendix 4. Ten of the macroplots were controls for 1988 treatments.

In 1989, field work was carried out between June 25 and August 10. Data were collected for 73 macroplots. Eleven blocks had been treated with glyphosate in late summer of 1988, but 3 of the 46 macroplots scheduled for treatment were not affected by the herbicide. These macroplots were not sampled in 1989. One control macroplot in the Phillips was damaged by drift from the helicopter spray and was included with the treated macroplots in the analyses. One block (CK08) along the Kilbella River was omitted from analyses because it was flooded in late September 1988 and the macroplots were either completely or partially buried by up to 20 cm of sand.

Each block was classified by site association (Banner *et al.* 1990), seral plant association (Hamilton 1988), and seral stage (Table 4). Site and soil characteristics for the macroplots are summarized in Appendix 5 and a complete list of plant species recorded on all plots is in Appendix 1.

TABLE 4. Ecological classification of sampled blocks

Block	Site association	Seral plant association[a]	Seral stage[b]
Phillips River:			
P01	Ss–Salmonberry	*Rubus spec.–Epilobium*	Shrub–Herb
P02	Ss–Salmonberry	*Sambucus* (*Rubus* sp.) *Epilobium*	Shrub–Herb
P03	CwSs–Skunk cabbage	(*Alnus*) *Rubus* sp.–*Lysichiton*	Pole–Sapling
P04	CwSs–Devil's club	*Rubus* sp.–*Epilobium*	Shrub–Herb
P05	BaCw–Devil's club	*Tiarella–Streptopus*	(Shrub–Herb)
P06	BaCw–Devil's club	*Rubus* sp.–*Epilobium*	(Shrub–Herb)
P07	BaCw–Foamflower	(*Rubus*) *Sambucus–Epilobium*	Shrub–Herb
P08	Ss–Salmonberry	*Rubus–Epilobium* (*Festuca*)	Shrub–Herb
Chuckwalla River:			
CK01	Ss–Salmonberry	*Rubus* sp.–*Trautvetteria*	Shrub–Herb
CK02	Ss–Salmonberry	(*Alnus*) *Rubus* sp.–*Trautvetteria*	Pole–Sapling
CK05	CwSs–Devil's club	*Rubus* sp.(*Rubus parv.*)–*Trautvetteria*	Shrub–Herb
CK06	Ss–Salmonberry	(*Alnus*) *Rubus* sp.–*Trautvetteria*	Pole–Sapling
Kilbella River:			
CK03	BaCw–Foamflower	*Rubus* (*Vaccinium*) –*Epilobium*	Shrub–Herb
CK04	Ss–Salmonberry	*Rubus* sp.–*Trautvetteria*	Shrub–Herb
CK07	Ss–Salmonberry	*Rubus* sp.–*Trautvetteria*	(Shrub–Herb)
CK08	Ss–Salmonberry	*Rubus* sp.–*Trautvetteria* (*Heracleum*)	Shrub–Herb
CK09	Ss–Salmonberry	(*Populus*) *Rubus* sp.–*Trautvetteria*	Pole–Sapling
Kingcome River:			
KG02	BaCw–Foamflower	*Rubus* sp.–*Epilobium*	Shrub–Herb
KG03	Ac–Red–osier dogwood	*Rubus* sp.–*Epilobium* (*Athyrium*)	Shrub–Herb
KG04	Ss–Salmonberry	(*Alnus*) *Rubus parv.–Trautvetteria*	Pole–Sapling
KG05	Ss–Salmonberry	*Rubus* sp.–*Athyrium*	Shrub–Herb
Klinaklini River:			
KN01–KN05[c]	Ss–Salmonberry	*Rubus id.–Epilobium/Elymus*	Shrub–Herb

[a] Nomenclature specific to this study (derived from seral plant association concept).
[b] Refers to predominant seral stage among the macroplots.
[c] "Blocks" KN01-KN05 are in the same cutblock.

Hack-and-squirt

The total percent cover of forage shrubs in treated blocks was not statistically different ($p \leq 0.10$) from the controls in either 1988 or 1989, or between years for any of the hack-and-squirt treatment types. However, some general trends were evident:

a) 1988 Hack-and-squirt with foliar underspray

Impacts on total forage shrub cover varied (Figure 2, Table 5). Salmonberry in KG04 were more severely damaged by the underspray than in P03 (Table 5). However, mean macrocover and mean microcover for all forage shrubs each decreased by 46% (difference in mean macrocover=-16; difference in mean microcover=-24) (Figure 3). Changes in Group A shrubs were similar to those for all shrubs (Figure 4a). Cover of Group B shrubs generally decreased (Figure 4b). In the less affected block (P03), changes in cover were inconsistent between macrocover and microcover (Table 5). The high and low shrub strata decreased but the herb strata increased (Table 6). On the plots in 1989, most herb species increased or new species appeared (Appendix 6). Salmonberry fruit production decreased by 63% to 83 g in 1989 (one macroplot sampled). *Vaccinium* production also decreased although there was not more than 25 g of fruit in either year (one macroplot sampled). Where impacts of the underspray were lower (P03), fruit abundance indices increased. Otherwise, they dropped to zero 1 year post-treatment (Table 7).

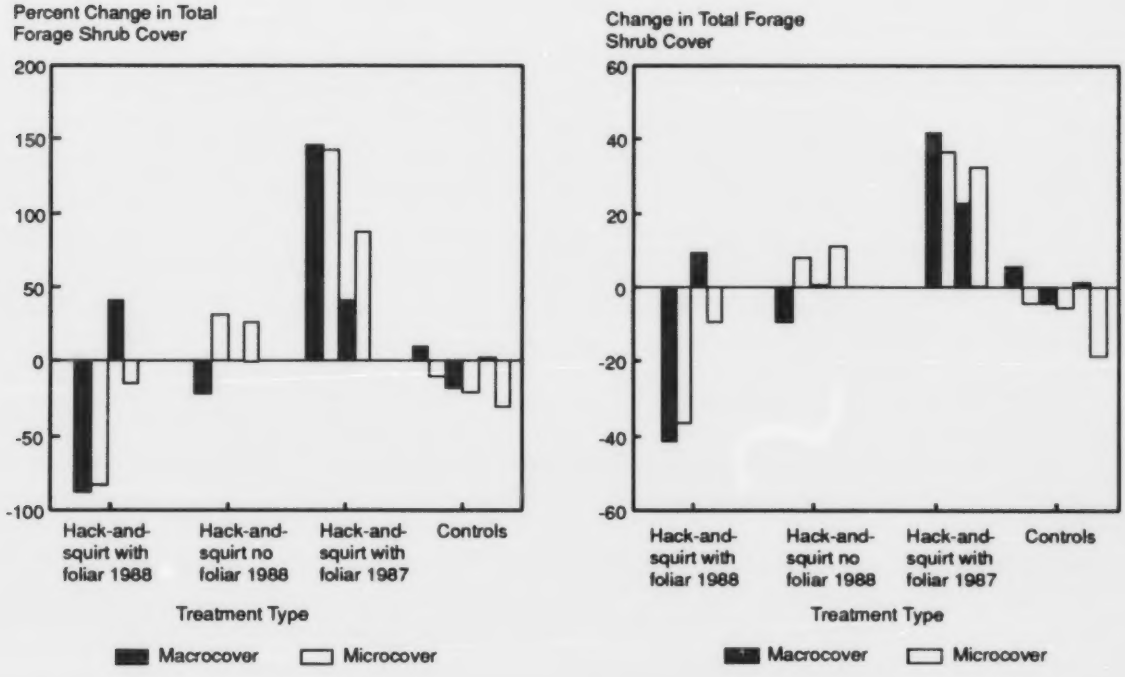

FIGURE 2. Changes in total forage shrub cover between 1988 and 1989 for hack-and-squirt treatments. Left: Percent change in cover for all forage shrubs grouped. Right: Absolute change in cover for all forage shrubs grouped. (Refer to Appendix 8, page 49, for an explanation of the graphing conventions used.)

b) 1988 Hack-and-squirt without foliar underspray

Impacts were varied (Figure 2, Table 5). Mean macrocover declined slightly (by 7%; difference= -5) for all shrubs, but mean microcover increased by 30% (difference=+11) (Figure 3). Changes in Group A and Group B shrubs were also varied (Figures 4a and 4b). The high shrub strata decreased while the low shrub strata was almost constant (Table 6). The herb strata increased (Table 6) as all herb species either increased in cover or remained unchanged (Appendix 6). Most species picked (highbush-cranberry, devil's club, stink currant, trailing black currant, and salmonberry) did not have more than 25 g of fruit in any year. However, all but devil's club and salmonberry had slightly more fruit in 1989. *Vaccinium* fruit production declined by 65% to less than 40 g (one macroplot sampled). Fruit abundance indices generally decreased after treatment although some fruit was present one year after treatment (Table 7).

c) 1987 Hack-and-squirt with foliar underspray

Total forage shrub cover increased between 1988 and 1989 (Figure 2). There was a 79% increase (difference=+32) in mean macrocover and an increase of over 100% (difference=+35) for mean microcover for all shrubs (Figure 3). Group A and Group B shrubs also increased (Figures 4a and 4b). Cover increased or was constant between 1988 and 1989 for all shrub species with percent cover ≥5% in at least 1 year (Table 5). The largest percent change in total shrub cover was in CK04 which appeared to have more impacts from the underspray than CK05, but the actual differences in percent cover were not that widely different for the two blocks (Figure 2). All strata increased, although the herb strata increased less between 1988 and 1989 than did the herb strata in blocks treated in 1988 (Table 6). Red elderberry had no fruit in 1988, but more than 200 g in 1989 (two macroplots sampled). Salmonberry production increased by over 700%, but there was an average of less than 40 g in 1989 (three macroplots sampled). Thimbleberry had no fruit in 1988 and only 15 g the following year (one macroplot sampled). Fruit abundance indices increased or remained the same between 1988 and 1989 (Table 7).

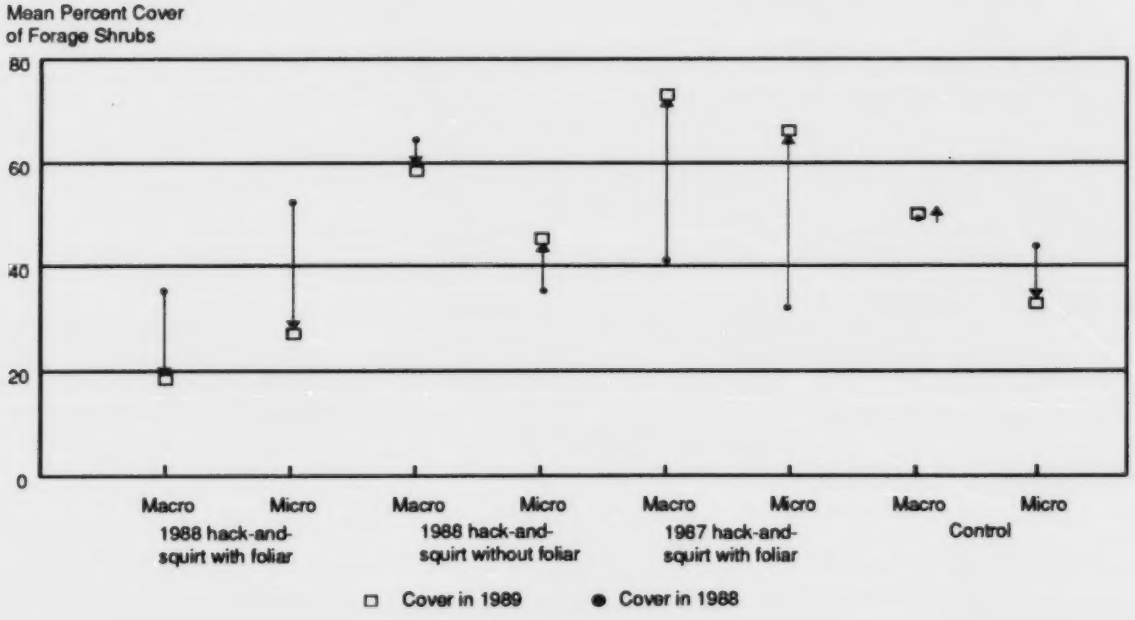

FIGURE 3. Changes in mean macrocover ("macro") and mean microcover ("micro") between 1988 and 1989 for all forage shrubs, hack-and-squirt treatments only. (Refer to Appendix 8, page 49, for an explanation of the graphing conventions used.)

TABLE 5. Percent change in cover (macrocover/microcover) between 1988 and 1989 for forage shrubs where cover ≥5% in at least 1 year, summarized by treatment type

Block	No. of macroplots	Forage shrubs								
		LONHINV	RUBUIDA	RUBUPAR	RUBUSPE	SAMBRAC	CORNSER	OPLOHOR	RIBEBRA	VACCIN[a]
1988 hack-and-squirt with foliar										
P03	1				67/-9				/-33	0/-18
KG04	2				-94/-92					
1988 hack-and-squirt without foliar										
CK06	3				23/36	-56/1008		-37/-100		
CK02[b]	6				-22/32					
1987 hack-and-squirt with foliar										
CK05	2			100/22	36/108	33/30			/new	
CK04	2			/700	300/98	327/673	0/75		/167	
Hack-and-squirt controls										
KG04	1			0/-20	-25/-27					
P03	1				0/-57					40/-8
CK01	1				-50/-48	150/	400/		300/38	
1988 foliar										
KG05	2				-33/-41	-90/	29/-36			
KG02	2				-91/-89	-93/-78				
P02	5				-79/-72	-23/-48				
P01	5				-71/-53	-25/14				
P04	6				-98/-94				-9/7	
KG03	2			-53/-75	-90/-99		20/161			
P03	1				-99/-79					/55
1987 foliar										
CK03	2				509/179					0/24
CK07	2				/277		50/			
P06	2				100/94					
P05	2									
1986 foliar										
P07	2				60/29	360/49				/32
P08	2				38/21					
Foliar controls										
KG05	1				0/38				0/-25	
P02	1				200/28				67/7	
Efficacy										
0.36 kg a.i./ha										
KN03	3		-60/-57							
0.71 kg a.i./ha										
KN01	3		87/39	-50/-6	/-26		5/-21			
1.42 kg a.i./ha										
KN04	3		-92/-97	/-73			-34/-24			
Controls										
KN02	3	-4/-45	/-1	6/7	25/-56					
KN05	1			/-11						

[a] See Appendix 1 for explanation of species codes.
[b] Some large shrubs cut down.

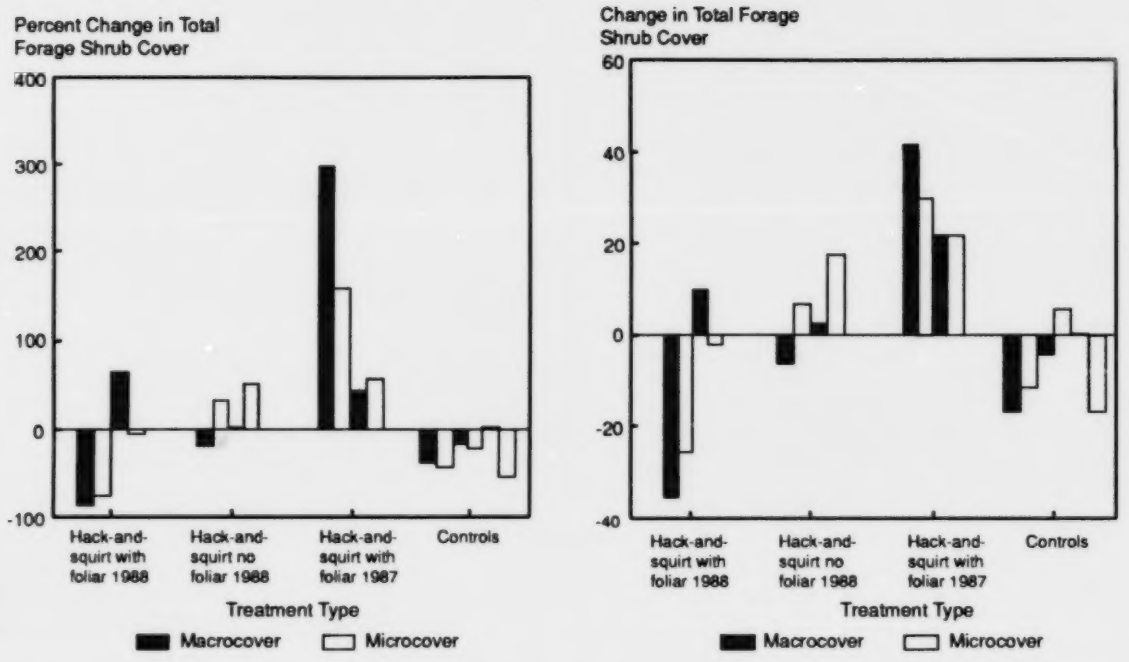

FIGURE 4a. Changes in total forage shrub cover between 1988 and 1989 for hack-and-squirt treatments. Left: Percent change in cover for Group A forage shrubs. Right: Absolute change in cover for Group A forage shrubs.

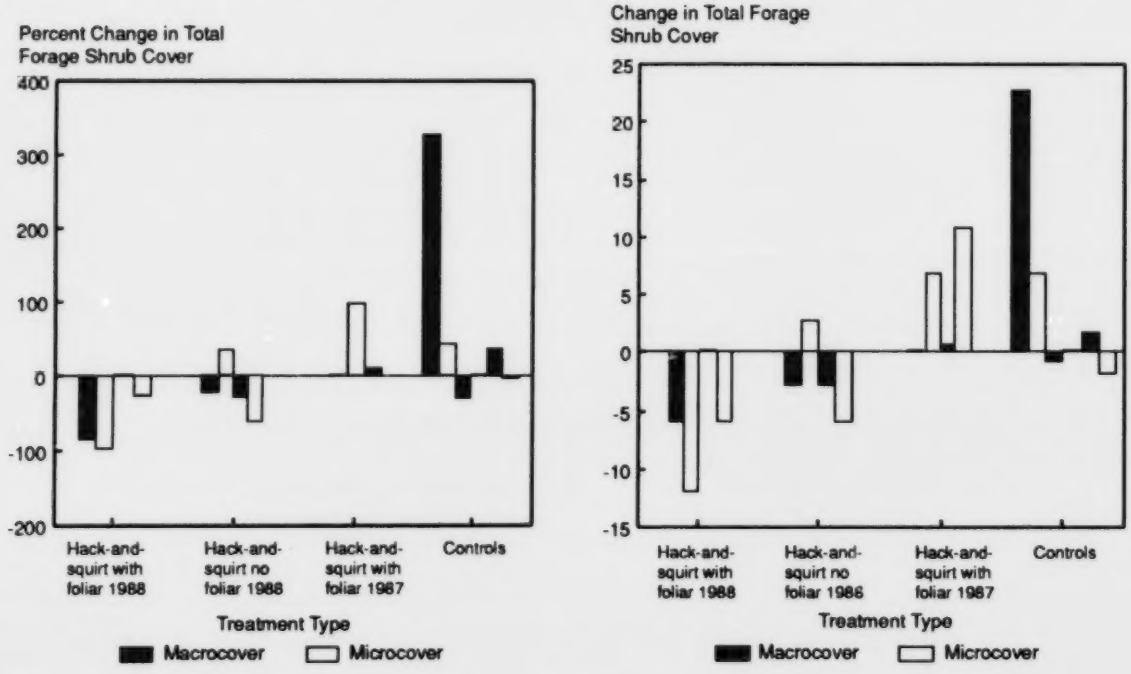

FIGURE 4b. Changes in total forage shrub cover between 1988 and 1989 for hack-and-squirt treatments. Left: Percent change in cover for Group B forage shrubs. Right: Absolute change in cover for Group B forage shrubs.

TABLE 6. Percent change in strata cover between 1988 and 1989, summarized by treatment type

Strata	1988 foliar			1987 foliar			1986 foliar			Foliar controls		
	1988	1989	% change	1988	1989	% change	1988	1989	% change	1988	1989	% change
Tree >10 m	0	0	0	0	0	0	0	0	0	0	0	0
High shrub 2–10 m	12	7	-47	1	4	344	2	7	200	42	47	12
Low shrub <2 m	48	16	-67	10	18	88	24	33	39	60	50	-17
Herb	42	35	-18	21	51	138	55	46	16	37	47	27
	1988 hack-and-squirt with foliar[a]			1988 hack-and-squirt without foliar[b]			1987 hack-and-squirt with foliar			Hack-and-squirt controls		
	1988	1989	% change	1988	1989	% change	1988	1989	% change	1988	1989	% change
Tree >10 m	40	0	-100	70	22	-69	<1	1	100	67	73	10
High shrub 2–10 m	55	30	-45	49	38	-21	24	42	76	35	38	9
Low shrub <2 m	21	9	-57	22	23	2	21	40	93	23	17	-25
Herb	32	47	46	20	35	72	57	66	15	26	27	7

[a] Deciduous canopy of P03 was in the high shrub strata.
[b] Some large shrubs in CK02 were cut down.

TABLE 7. Fruit abundance indices for all macroplots with fruit in hack-and-squirt treatments and controls (lowest abundance=0.5, highest abundance=294.0)

Macroplot	Species	1988	1989
1988 hack-and-squirt with foliar			
KG04 T01	RUBUSPE	7.0	0.0
KG04 T02	RUBUSPE	3.5	0.0
KG04 T02	SAMBRAC	3.5	0.0
P03 T05	RUBUSPE	114.0	189.0
P03 T05	VACCINI	31.0	76.0
1987 hack-and-squirt with foliar			
CK04 T01	RUBUSPE	3.5	31.0
CK04 T02	SAMBRAC	0.0	76.0
CK04 T02	RUBUSPE	3.5	76.0
CK05 T01	RUBUSPE	3.5	31.0
CK05 T01	RUBUPAR	0.0	31.0
CK05 T02	RUBUPAR	76.0	76.0
CK05 T02	SAMBRAC	0.0	76.0
Hack-and-squirt controls			
KG04 C03	RUBUSPE	3.5	0.0
P03 C04	RUBUSPE	76.0	114.0
P03 C04	VACCINI	46.5	31.0
CK01 C01	RUBUSPE	3.5	0.0
1988 hack-and-squirt no foliar			
CK02 T01	RUBUSPE	31.0	0.0
CK02 T01	RIBELAX	3.5	3.5
CK02 T01	CORNSER	76.0	0.0
CK02 T02	RUBUSPE	7.0	0.5
CK02 T02	VIBUEDU	0.0	3.5
CK02 T04	RUBUSPE	3.5	0.0
CK02 T05	RUBUSPE	3.5	0.0
CK02 T06	OPLOHOR	31.0	15.5
CK06 T01	RUBUSPE	31.0	3.5
CK06 T01	VACCINI	256.5	171.0
CK06 T02	OPLOHOR	85.5	15.5
CK06 T02	SAMBRAC	126.0	76.0
CK06 T02	RUBUSPE	31.0	3.5
CK06 T02	RIBEBRA	0.0	7.0

d) Hack-and-squirt controls

No trend was evident for the controls, although changes in total forage shrub cover were generally less than in the treated blocks (Figure 2). Mean macrocover for all shrubs was essentially constant between 1988 and 1989 (increase of 2%, difference=+1) (Figure 3). Mean microcover for all shrubs decreased by 23% (difference=-10) (Figure 3). Group A shrubs decreased; Group B shrubs generally

increased (Figures 4a and 4b). It appeared that salmonberry was declining in the controls (Table 5). The high shrub strata increased while the low shrub strata decreased (Table 6). The herb strata increased slightly (Table 6) and the percent cover of most herbs species either increased or was constant (Appendix 6). Salmonberry fruit production increased by 17% to an average of 126 g in 1989 (three macroplots sampled). *Vaccinium* production increased from 15 to 22 g (one macroplot sampled). Fruit abundance indices decreased in all but one instance (Table 7).

Foliar

a) 1988 foliar

The total percent cover of forage shrubs was significantly different from the controls for macrocover and microcover of all shrubs ($p<0.10$) and Group A shrubs ($p<0.05$). Although these results do not indicate whether the significant differences were between years or within years, it is apparent that total forage shrub cover decreased dramatically 1 year post-treatment (Figure 5). Mean macrocover decreased 67% (difference=-41) and mean microcover decreased 59% (difference=-33) for all shrubs (Figure 6). Group A shrubs also declined (Figure 7a). A trend was not apparent for Group B shrubs (Figure 7b). Impacts to stink currant, red-osier dogwood, and *Vaccinium* were more varied and less severe than for red elderberry, salmonberry, and thimbleberry (Table 5). All strata decreased (Table 6). In some blocks, decreases in shrub strata cover were greater than 90%. Among the herbs, lady fern (*Athyrium filix-femina*), spiny wood fern (*Dryopteris assimilis*), three-leaved foamflower (*Tiarella trifoliata*), and enchanter's nightshade (*Circea alpina*) seemed particularly sensitive to glyphosate. False bugbane (*Trautvetteria caroliniensis*), however, appeared to increase 1 year post-treatment (Appendix 6). Salmonberry production decreased from an average of 56 g to zero in 1989 (13 macroplots sampled). *Vaccinium* fruit production decreased from an average of 22 g to less than 2 g (six macroplots sampled). In contrast, red elderberry increased 9% from an average of 529 g to 579 g (11 macroplots sampled). Fruit abundance indices remained high for red-osier dogwood and trailing blackberry and sometimes remained high for red elderberry and thimbleberry after treatment (Table 8).

b) 1987 foliar

The only significant difference after the 1987 foliar treatments was for macrocover of Group A shrubs ($p<0.10$). However, total forage shrub cover and Group A and Group B shrub cover all increased (Figures 5, 7a and 7b). There was an increase in mean macrocover of over 100% (difference=+11) and of almost 150% (difference=+10) for mean microcover for all shrubs (Figure 6). Cover increased or was constant between 1988 and 1989 for all forage shrubs with cover ≥5% in at least 1 year (Table 5). All strata increased (Table 6). All herbs were either increasing or constant except for false bugbane, which declined as it also had in the 1987 hack-and-squirt blocks (Appendix 6). *Vaccinium* fruit production went from almost zero in 1988 to 362 g 1989 (two macroplots sampled). Salmonberry production also increased, from an average of 34 g to 89 g (three macroplots sampled). Fruit abundance indices increased substantially between 1988 and 1989 (Table 8).

c) 1986 foliar

The total percent cover of forage shrubs was not statistically different from the controls in either 1988 or 1989, or between years for 1986 foliar treatments. It appears, however, that cover for all shrubs and for Group A shrubs increased (Figures 5 and 7a), although generally not as much as in the 1987 treatments. There was a 60% increase (difference=+15) in mean macrocover and a 27% increase (difference=+9) in mean microcover for all shrubs (Figure 6). Group B shrubs increased in one block and declined in the other (Figure 7b). Cover of all shrubs with cover ≥5% in at least 1 year increased or was constant (Table 5). The high and low shrub strata increased but the herb strata decreased (Table 6). There were fewer herb species and their cover changes were more variable than for the other foliar treatments (Appendix 6). Salmonberry production increased by 142% to an average of 129 g in 1989 (two macroplots sampled). Red elderberry had no fruit in 1988, but by 1989 there was an average of 30 g (two macroplots sampled). Fruit abundance indices mainly increased between 1988 and 1989 (Table 8).

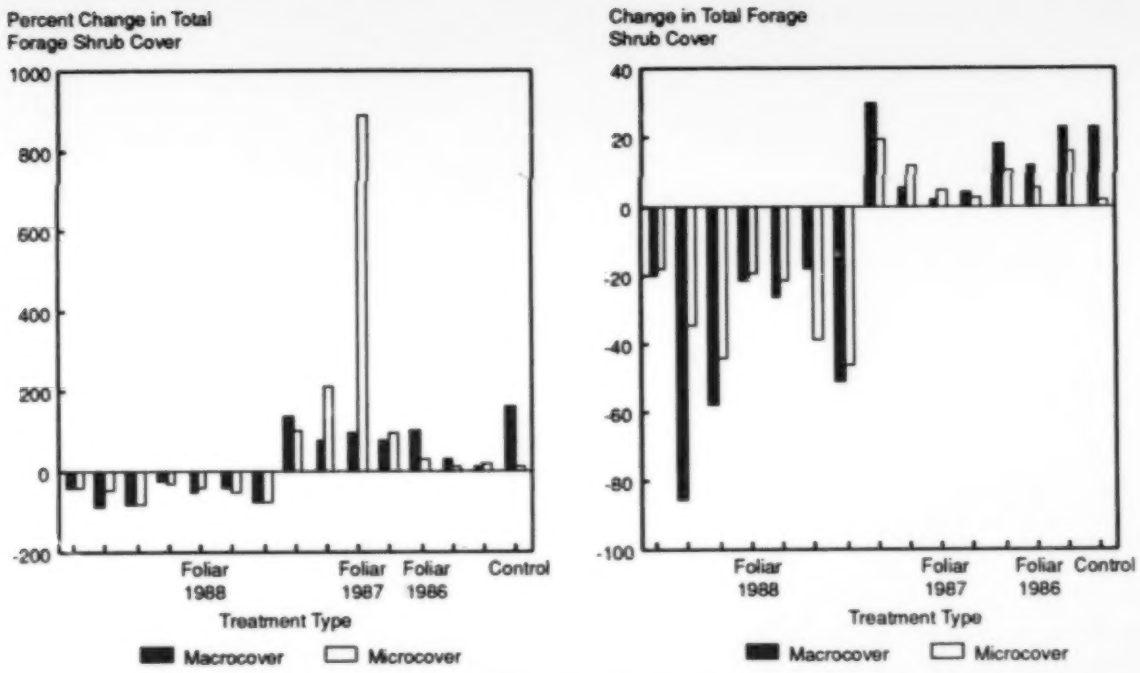

FIGURE 5. Changes in total forage shrub cover between 1988 and 1989 for foliar treatments. Left: Percent change in cover for all forage shrubs grouped. Right: Absolute change in cover for all forage shrubs grouped.

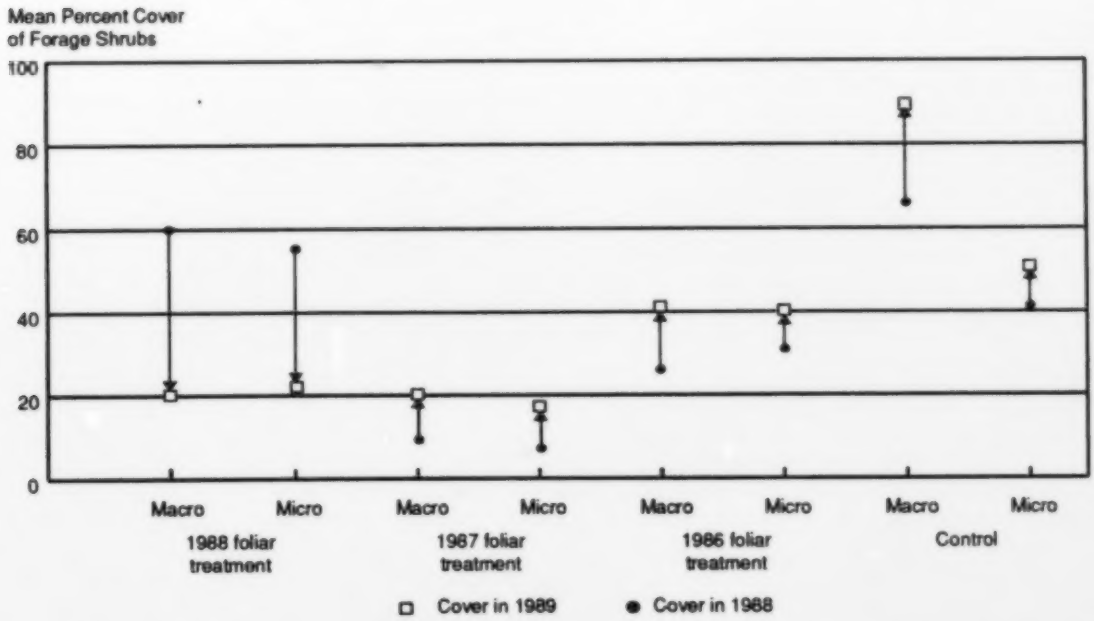

FIGURE 6. Absolute changes in mean macrocover ("macro") and mean microcover ("micro") between 1988 and 1989 for all forage shrubs, foliar treatments only.

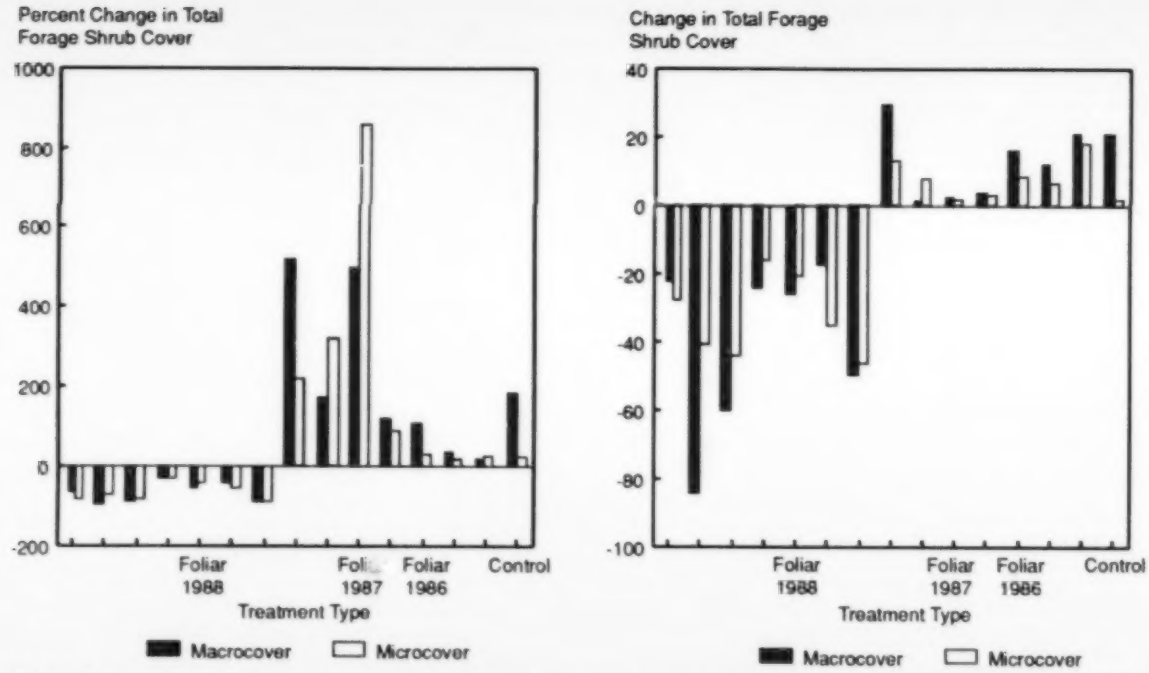

FIGURE 7a. Changes in total forage shrub cover between 1988 and 1989 for foliar treatments. Left: Percent change in cover for Group A forage shrubs. Right: Absolute change in cover for Group A forage shrubs.

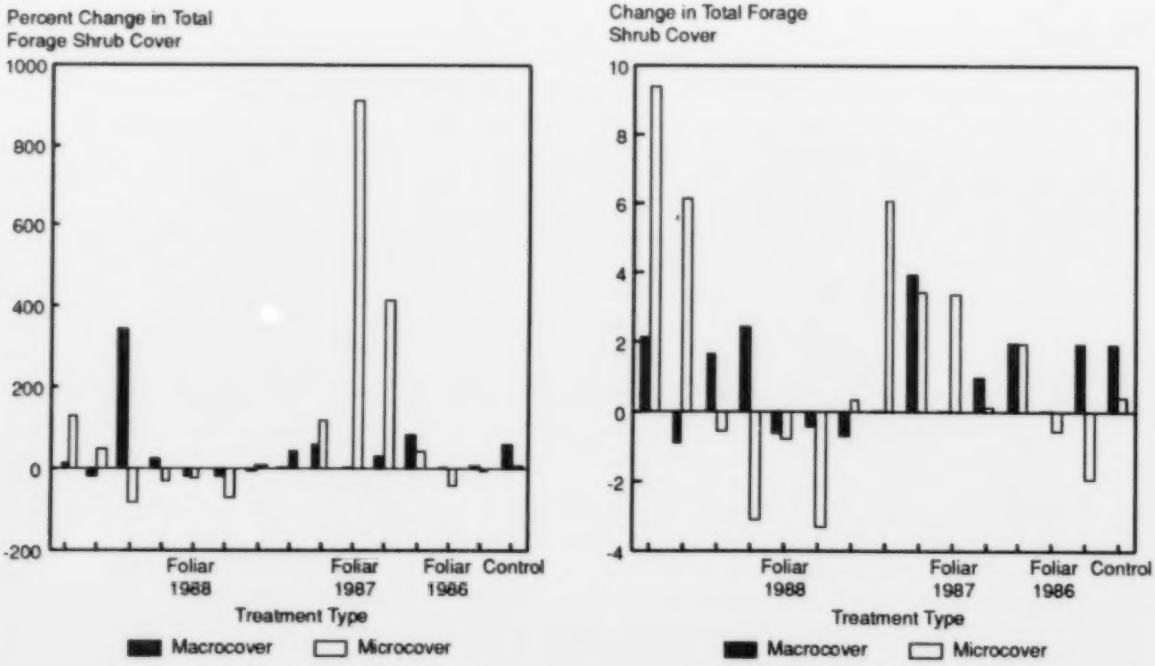

FIGURE 7b. Changes in total forage shrub cover between 1988 and 1989 for foliar treatments. Left: Percent change in cover for Group B forage shrubs. Right: Absolute change in cover for Group B forage shrubs.

TABLE 8. Fruit abundance indices for all macroplots with fruit in foliar treatments and controls (lowest abundance=0.5, highest abundance=294.0)

Macroplot	Species	1988	1989	Macroplot	Species	1988	1989
1988 foliar							
KG02 T01	SAMBRAC	126.0	0.0	P03 T06	VACCALA	3.5	0.0
KG02 T01	RUBUSPE	76.0	0.0	P04 T02	RUBUSPE	126.0	0.5
KG02 T02	SAMBRAC	114.0	3.5	P04 T02	VACCINI	15.5	0.0
KG02 T02	RUBUSPE	76.0	0.0	P04 T03	RUBUSPE	31.0	0.0
KG03 T02	RUBUPAR	76.0	114.0	P04 T03	RIBEBRA	0.5	0.5
KG03 T02	RUBUSPE	3.5	0.0	P04 T04	RUBUSPE	76.0	0.0
KG05 T02	CORNSER	76.0	189.0	P04 T04	SAMBRAC	76.0	114.0
KG05 T02	SAMBRAC	15.5	0.0	P04 T05	RUBUSPE	189.0	0.0
P01 T02	RUBUSPE	0.5	0.0	P04 T06	RUBUSPE	15.5	0.0
P01 T02	SAMBRAC	256.5	126.0				
P01 T02	VACCALA	3.5	0.5	*1987 foliar*			
P01 T03	RUBUSPE	0.5	0.0				
P01 T03	RUBUPAR	38.0	3.5	CK03 T02	VACCINI	3.5	256.5
P01 T03	SAMBRAC	256.5	256.5	CK03 T02	RUBUSPE	3.5	76.0
P01 T04	RUBUSPE	0.5	0.0	CK07 T01	CORNSER	15.5	171.0
P01 T04	VACCOVA	3.5	0.0	CK07 T01	VIBUEDU	0.0	7.0
P01 T05	RUBULEU	114.0	114.0	P05 T01	VACCINI	0.0	31.0
P01 T06	RUBUSPE	7.0	0.0	P05 T02	RUBUSPE	3.5	7.0
P01 T06	SAMBRAC	256.5	256.5				
P01 T06	VACCINI	114.0	0.0	*1986 foliar*			
P02 T01	SAMBRAC	0.5	7.0				
P02 T01	RUBUSPE	0.5	0.0	P07 T01	RUBUSPE	126.0	114.0
P02 T02	SAMBRAC	3.5	0.5	P07 T01	SAMBRAC	0.0	3.5
P02 T02	RUBUSPE	0.5	0.0	P07 T02	VACCINI	3.5	0.0
P02 T03	VACCPAR	126.0	15.5	P07 T02	RUBULEU	31.0	189.0
P02 T04	SAMBRAC	76.0	0.0	P07 T02	SAMBRAC	0.0	31.0
P02 T04	RUBUSPE	3.5	0.0	P08 T01	RUBUSPE	0.0	3.5
P02 T05	SAMBRAC	126.0	0.0				
P02 T05	RUBUSPE	3.5	0.0	*Foliar control*			
P03 T06	RUBUSPE	31.0	0.0				
P03 T06	VACCPAR	114.0	0.0	KG05 C03	RIBEBRA	0.0	15.5
				P02 C06	RUBUSPE	0.5	0.5

d) Foliar controls

Total forage shrub cover and Group A and Group B forage shrub cover generally increased (Figures 5, 7a and 7b), although changes in cover for individual species were varied (Table 5). Mean macrocover increased by 35% (difference=+23) and mean microcover increased by 23% (difference=+9) for all shrubs (Figure 6). The high shrub strata was constant and the low shrub and herb strata increased (Table 6). There was little fruit in the controls—only stink currants were picked. There was more fruit in 1989, but the total was less than 10 g (one macroplot sampled).

A salmonberry shrub was marked in 1988 in a block treated aerially in 1987 (CK07). Most salmonberry in the block appeared to be dead in 1988. Some plants showed minimal recovery from the base. The marked stem had typical symptoms of glyphosate damage—dwarfed, undifferentiated vegetative growth at stem nodes—and was dead in 1989. Generally throughout the block, however, there was regrowth from base of severely damaged stems and new canes were present. A few stems still had malformed leaf growth.

Combined herbicide and manual treatment

A block (CK09) in the Kilbella watershed was treated with a combination of foliar glyphosate application and manual cottonwood control in 1984. The small sample size (two macroplots) did not allow for analyses comparable to those for strictly foliar treatments. However, it was apparent

from field observations that the manual method failed to control cottonwood. The main stem resumed growth at the point where it was cut, and 5 years after treatment the deciduous cover once again overtopped any conifers present.

3.1.2 Glyphosate efficacy trial

The total percent cover of forage shrubs treated was not statistically different from the controls in either 1988 or 1989, or between years for any of the application rates. However, some general trends were evident:

a) 0.36 kg a.i./ha

Decreases in total forage shrub cover and Group A cover were greater than at 0.71 kg a.i./ha (Figures 8a and 8b). Group B shrubs decreased in macrocover but increased in microcover (Figure 8c). Red raspberry, the only species with cover ≥5%, decreased (Table 5). The only increase in the high shrub strata was at this rate (Table 9). Red raspberry was the only species with fruit, but yield and the abundance index (one macroplot sampled) decreased to zero in 1989 (Table 10). A highbush-cranberry shrub was marked in 1988. Fruit was picked that year (130 g) and again in 1989 (5 g). After treatment, most leaves were reddish brown, and some were dried out but still attached. Several shoot tips were dead but new tips were growing.

TABLE 9. Percent change in strata cover between 1988 and 1989, summarized by glyphosate application rate

	0.36 kg a.i./ha			0.71 kg a.i./ha			1.42 kg a.i./ha		
Strata	**1988**	**1989**	**% change**	**1988**	**1989**	**% change**	**1988**	**1989**	**% change**
Tree >10 m	0	0	0	0	0	0	0	0	0
High shrub 2–10 m	3	5	67	52	8	-84	12	10	-14
Low shrub <2 m	23	13	-43	37	33	-9	21	4	-81
Herb	73	65	-11	77	75	-2	82	60	-26

	Control 1			Control 2		
	1988	**1989**	**% change**	**1988**	**1989**	**% change**
Tree >10 m	0	0	0	0	0	0
High shrub 2–10 m	10	20	100	17	13	-20
Low shrub <2 m	40	30	-25	27	33	22
Herb	75	80	7	83	78	-6

TABLE 10. Fruit abundance indices for all macroplots with fruit, summarized for different glyphosate application rates and controls (lowest abundance=0.5, highest abundance=294.0)

Macroplot	**Species**	**1988**	**1989**	**Macroplot**	**Species**	**1988**	**1989**
0.36 kg a.i./ha				*1.42 kg a.i./ha*			
KN03 T02	RUBUIDA	31.0	0.0	KN04 T01	CORNSER	76.0	7.0
				KN04 T01	RUBUSPE	31.0	0.0
0.71 kg a.i./ha				KN04 T02	CORNSER	7.0	0.0
				KN04 T02	SAMBRAC	38.0	0.0
KN01 T01	RUBUIDA	114.0	126.0	KN04 T03	RUBUIDA	76.0	0.0
KN01 T01	CORNSER	76.0	7.0				
KN01 T01	RUBUPAR	7.0	0.0	*Controls*			
KN01 T02	RUBUPAR	7.0	0.0				
KN01 T02	RUBUIDA	76.0	114.0	KN02 C01	RUBUIDA	7.0	0.0
KN01 T03	VIBUEDU	0.0	3.5	KN02 C02	LONIINV	256.5	171.0
KN01 T03	RUBUIDA	0.0	7.0	KN02 C03	LONIINV	256.5	256.5

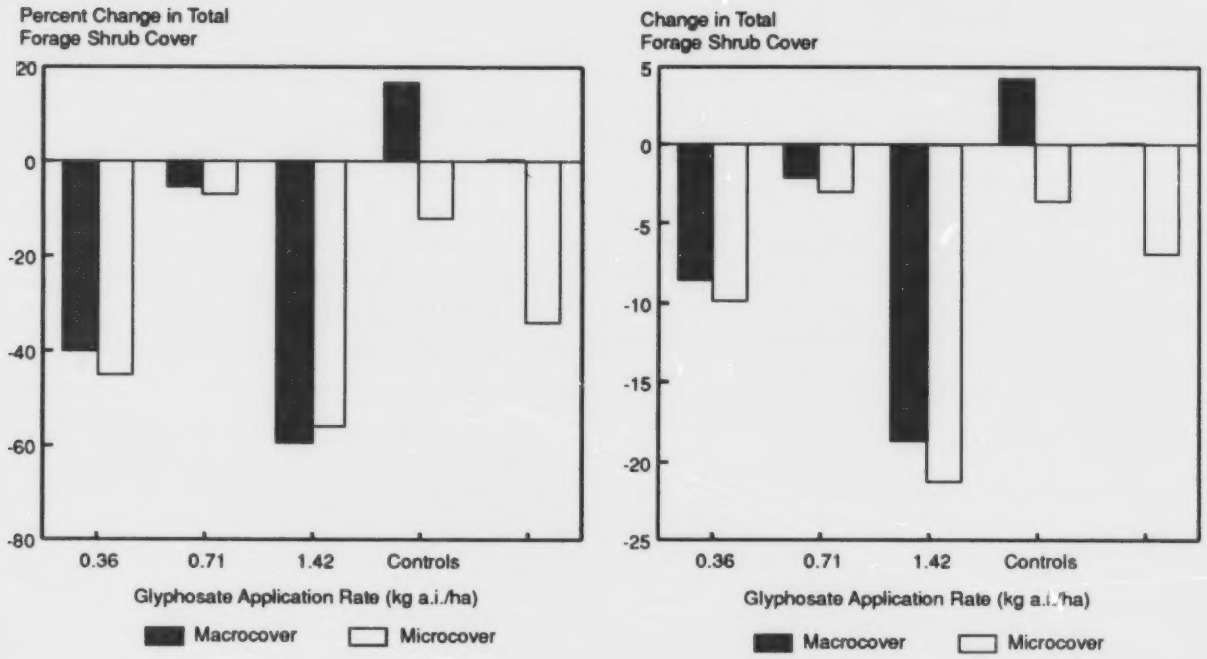

FIGURE 8a. Changes in total forage shrub cover between 1988 and 1989 for the efficacy trial. Left: Percent change in cover for all forage shrubs grouped. Right: Absolute change in cover for all forage shrubs grouped.

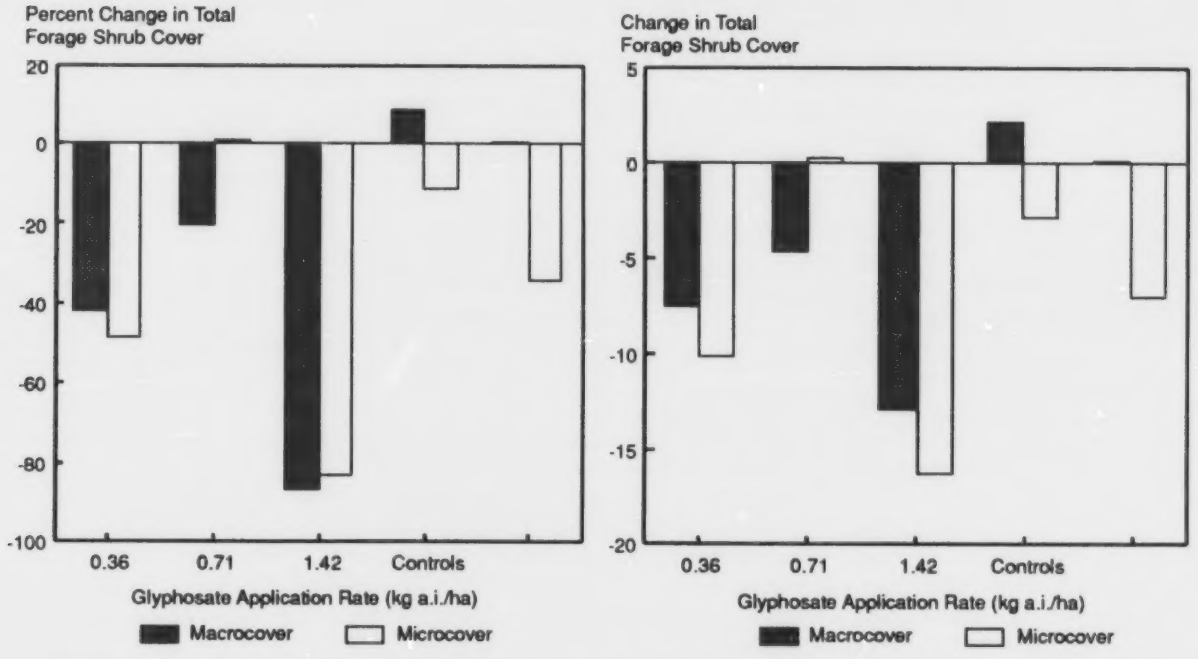

FIGURE 8b. Changes in total forage shrub cover between 1988 and 1989 for the efficacy trial. Left: Percent change in cover for Group A forage shrubs. Right: Absolute change in cover for Group A forage shrubs.

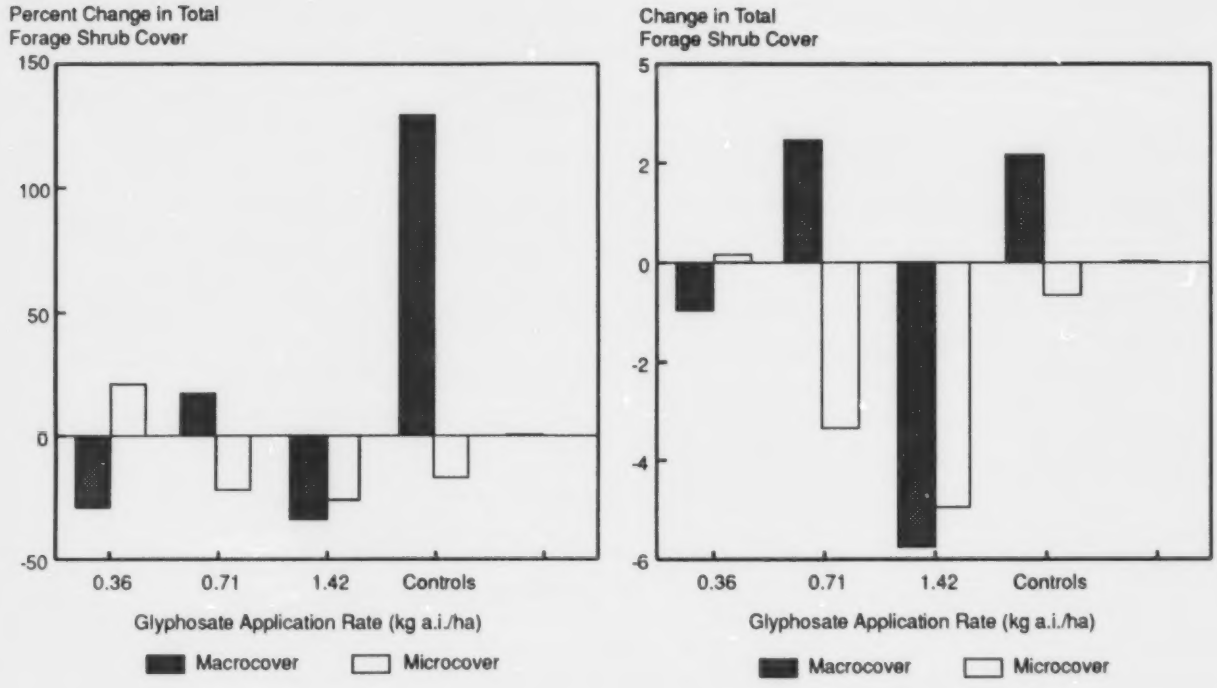

FIGURE 8c. Changes in total forage shrub cover between 1988 and 1989 for the efficacy trial. Left: Percent change in cover for Group B forage shrubs. Right: Absolute change in cover for Group B forage shrubs.

b) 0.71 kg a.i./ha

Decreases in total forage shrub cover were smallest at this rate (Figure 8a). This was also true for Group A macrocover, although microcover increased slightly (Figure 8b). Group B shrubs increased in macrocover and decreased in microcover (Figure 8c). Red raspberry increased, while salmonberry, thimbleberry, and red-osier dogwood generally decreased (Table 5). Low and high shrub strata decreased; the herb strata remained essentially constant (Table 9). Red raspberries increased by over 250% to an average of 58 g 1 year post-treatment (three macroplots sampled). The fruit abundance indices of red-osier dogwood and thimbleberry fruit decreased (Table 10).

c) 1.42 kg a.i./ha

The greatest decreases in total forage shrub cover and Group A and Group B shrub cover were at this rate (Figures 8a, 8b and 8c). Cover decreased for all shrubs with percent cover ≥5% in at least 1 year (Table 5). The high shrub strata decreased less than at 0.71 kg a.i./ha, while the low shrub strata decreased much more (Table 9). Although the herb strata decreased, there were still species that increased: blue wildrye (*Elymus glaucus*), sweet-scented bedstraw (*Galium triflorum*), large-leaved avens (*Geum macrophyllum*), bluegrass (*Poa* spp.), common dandelion (*Taraxacum officinale*), and nodding trisetum (*Trisetum cernuum*) (Appendix 7). Three berry species were picked in 1988 (each sampled from one macroplot), but no fruit was available the next year. Fruit abundance indices decreased to zero post-treatment in all but one case (Table 10). Two salmonberry shrubs were marked in the area in 1988. Both shrubs had similar herbicide damage in 1989. Canes were top-killed and most vegetative growth near the ground was malformed and very chlorotic. The marked salmonberry were growing under red-osier dogwood that had relatively light glyphosate damage.

d) Controls

Changes in total forage shrub cover were varied (Figure 8a). Macrocover increased or remained the same while microcover decreased. There were no Group B species in the control block KN05. Changes in the shrub strata were also varied (Table 9). There was a small increase in the herb strata in one control and a decrease in the other. Results were varied, although most species with ≥5% cover decreased (Table 5). Black twinberry was the only species with any fruit. Fruit abundance indices were high in both years (Table 10), although the amount of berries picked declined by 78% to 111 g in 1989 (two macroplots sampled).

3.2 Watershed Habitat Mapping

The habitat map produced for the Chuckwalla–Kilbella roughly corresponds to the area that could be harvested using conventional techniques. Non-commercial habitat types are included within this boundary. Approximately 35% (over 4000 ha) of this area was logged before 1990. The majority of this logging (54%) occurred on lower slopes and the valley bottom (elevation <500 ft). Approximately 90% of the area logged in the watershed is under 1500 ft in elevation.

The total land area less than 500 ft is 5062 ha. Forty-five percent (2282 ha) of this area was logged before 1990, 44% (2213 ha) is potentially commercial but unlogged, and the rest is non-commercial or unclassified. Sixty-seven percent (1489 ha) of the unlogged potentially commercial habitats are 80 or more years old. It appears that the land area covered by mature and old-growth seral stages of the commercial forest habitats has declined by 60% since logging began.

Glyphosate use is also concentrated in the lower elevations. A total of 777 ha were treated with glyphosate between 1984 and 1989. An additional 180 ha are proposed for 1990-1992. Fifty-nine percent of these treatments are on sites less than 500 ft and almost all (98%) are less than 1500 ft.

The habitats most affected by logging and subsequent silvicultural activities are commercial forest and logged areas used for berry feeding. The availability of other important habitats may change (e.g., skunk cabbage swamps may no longer be present after logging), but it is the season 3 habitats—on which grizzly bears depend for fruit—that are the most commonly affected and cover the greatest area. Many fruit-bearing species are available, but there are only a limited number of habitat types that produce enough fruit. Most of these are found at lower elevations and are potentially commercial forest (Hamilton 1987).

When the glyphosate impact model in Appendix 3 is applied to data for the Chuckwalla-Kilbella, high value habitat decreased by 10% and medium value habitat decreased by 5%. Concurrently, low value habitat increased by 5% and habitat of no value increased by 52%. In other seasons of bear use, the major shifts in habitat value after glyphosate treatment were from low to no value.

Almost all the area ranked as high value during season 3 in the Chuckwalla-Kilbella is on fluvial plains and fans (Floodplain/Fan habitat types). Eighty-five percent of the 2835 ha of Floodplain/Fan habitat (FF) is less than 500 ft in elevation, but only 68% of this is ranked as high value season 3 habitat (1653 ha). Between 1986 and 1989, 245 ha of FF were treated with glyphosate. This represents a 12% loss of high value season 3 habitat.

3.3 Forestry-related Glyphosate Use in the CWH

Twenty percent (18 239 ha) of the total area proposed for treatment (90 252 ha) in the CWH under permits with start dates from 1985 to 1988 was in occupied grizzly bear habitat (Table 11). Almost 15% (5477 ha) of the total area (37438 ha) treated with glyphosate between 1986 and 1988 in the Vancouver and Prince Rupert Forest Regions (Humphreys 1987, 1988, 1989) was in occupied grizzly bear habitat. An average of 1826 ha was treated annually with glyphosate in occupied grizzly bear habitat in the CWH between 1986 and 1988 (Table 12). This was 23% of the average area (7866 ha) treated annually in the entire CWH for that period. Information on 1985 glyphosate use was not included in the analysis because the follow-up reporting requirements of the Pesticide Control Branch were not enforced at that time.

A total of 14 035 ha were treated by foliar methods (e.g., backpack, mist blower, fixed wing) and 9383 ha by individual stem methods in the CWH between 1986 and 1988 (Table 13). Thirty-three percent (4622 ha) of the foliar treatments and 9% (855 ha) of the individual stem treatments were in occupied grizzly bear habitat.

TABLE 11. Forestry-related glyphosate use in the CWH zone for permits with start dates from 1985 to 1988. Summary of area proposed for treatment and area actually treated (to December 1988).

Permit status	Treatment area (ha) proposed	No. permits	Area (ha) sprayed	Percent of proposed area sprayed
For occupied grizzly bear habitat in the CWH				
Active	5 194	26	971	19
Applied for	639	1	na	na
Completed	12 406	80	5 495	44
Total	**18 239**	**107**	**6 466**	**35**
For the rest of the CWH				
Total	**72 013**	**392**	**21 527**	**30**
For all of the CWH				
Total	**90 252**	**499**	**27 994**	**31**

TABLE 12. Forestry-related glyphosate use in the CWH zone, 1985–88, summarized by year

Year	Total area treated (ha)	Area treated in occupied grizzly bear habitat (ha)	Percent of total area treated that is in occupied grizzly bear habitat
1985	4395	989	22
1986	5138	1564	30
1987	8890	2402	27
1988	9570	1511	16

TABLE 13. Forestry-related glyphosate use in the CWH zone, 1985–88, summarized by application method

Year	Truck spray boom	Back-pack	Mist blower	Power hose/ nozzle	Stem injection	Stump application	Fixed wing	Heli-copter	Other
Total area treated (ha)									
1985	32	594	101	180	342	430	0	2699	16
1986	17	378	276	233	1431	42	0	2680	82
1987	233	600	411	775	2898	1112	41	2725	95
1988	323	243	410	724	1168	2731	512	3454	3
Area treated in occupied grizzly bear habitat (ha)									
1985	25	10	2	0	27	0	0	925	0
1986	7	65	66	51	134	0	0	1241	0
1987	0	30	83	90	251	364	41	1542	0
1988	0	37	204	57	80	26	41	1066	0
Percent total area treated that is in occupied grizzly bear habitat									
1985	76	2	2	0	8	0	0	34	0
1986	44	17	24	22	9	0	0	46	0
1987	0	5	20	12	9	33	100	57	0
1988	0	15	50	8	7	1	8	31	0

4 DISCUSSION

4.1 Field Data Collection

4.1.1 Limitations

Duration

Short-term impacts of operational use of glyphosate on grizzly bear forage were examined. Although limited information on longer term impacts was collected on sites treated before 1988, data are inconclusive because pre-treatment data were unavailable. The 2-year study duration did not allow detailed investigation of the impact of glyphosate treatment on succession. Glyphosate use may accelerate the succession of conifer plantations to a closed-canopy stage with a depauperate understory.

Data collected

An ocular estimate of cover was chosen as the principal means of monitoring herbicide impacts on grizzly bear forage species. However, this estimate is subject to error, particularly when cover is low (e.g., <5%). Dividing the vegetation into height classes helped reduce error by confining estimates to a single stratum (e.g., high shrub), but this method is not sensitive to minor changes. Results must therefore be interpreted with care, as percent changes of <10% between 1988 and 1989 may be a result of estimation error. Assessment of impacts on grizzly bear forage is based not only on the magnitude and direction of changes in cover after treatment, but also on the amount of forage available pre-treatment. That is, although the impact may appear to be severe, if shrub cover was low before treatment then the change in forage availability would be minor.

Variation within strata between years was evident even when no treatment was applied. Some of the differences between years are due to natural changes in floristics and structure. Such changes are a normal part of the vegetation dynamics on the productive alluvial and fan ecosystems in the CWH. Growth rates in these ecosystems can be extremely high.[6]

Differences between the macrocover and microcover values were common. Microcover was averaged from cover estimates for a total of 4 m^2 of the 25 m^2 macroplot. Inaccuracies may occur if a species was low or patchy cover. For example, a plant present in the macroplot may not occur in any of the microplots. Alternatively, cover values derived from microplots may include small (young) plants that could be overlooked when cover is being estimated over the entire macroplot.

Controls

It was difficult to establish suitable controls. Problems included controlling drift from aerial applications, and finding sites that had the same ecological characteristics as areas scheduled for treatment. Even with co-operation from the licensees, only 10 control macroplots were established for the 1988 treatments. Nine of these were used in the analyses.

Sampling design and analysis

Rather than confining sampling to a small number of sites, plots were established across a variety of soil conditions and seral associations. Sites varied in logging history, glyphosate efficacy, and floristics and structure. Data from the different watersheds were pooled to make statistical comparisons possible. Although the sampling design ensured that impacts were examined over a wide range of operational treatments, it limited the number and kinds of analyses. Block data were not weighted by the number of macroplots within that block; averages were first calculated over the block, then grouped with averages for other blocks of the same treatment type. The average number

[6] See, for example, D'Anjou 1989.

of macroplots per treatment type was 8.5, but ranged from 3 to 23. Other researchers have compared pre- and post-herbicide treatment data using analysis of variance and paired t-tests (e.g., Freedman *et al.* 1988). Analyses were restricted to the Kruskal-Wallis test, therefore some statistically significant results may have been missed. Again, the emphasis was on gathering information that would be useful in determining the impacts over a wide range of operational treatments, not on collecting statistically rigorous data on a small number of sites.

Herbicide treatment

Comparability of results was limited by variations in the effectiveness of the operational treatments. Many studies (e.g., Balfour 1989) have shown differences in glyphosate efficacy to be due to a variety of factors such as weather, phenology of targets, and application rate and method. Impacts were particularly patchy in aerially treated blocks. Variation in impacts may also have been the result of restricted worker access in some of the more densely vegetated sample blocks.

4.1.2 Herbicide Impacts

Despite its limitations, this study clearly demonstrates the substantial impacts of glyphosate use on grizzly bear forage availability.

Hack-and-squirt

Canopy reduction in the hack-and-squirt blocks varied, particularly when the treatment was combined with girdling. It appeared that the smaller the deciduous tree, the greater the likelihood of control with glyphosate. The shrub layer was significantly affected when the treatments were combined with foliar undersprays or when shrubs were cut down manually.

The shrub layer can apparently recover within 2 years after a hack-and-squirt treatment combined with underspray. Cover and fruit abundance increased substantially between 1988 and 1989 for blocks treated in 1987, but since pre-treatment information on these blocks was not available, we do not know whether this represents recovery to or beyond the original productivity level.

Hack-and-squirt treatments without underspray may actually enhance shrub cover and fruit production. However, data from this study are inconclusive as changes in cover are within the range of sampling error and are inconsistent between macrocover and microcover. In addition, no 1987 hack-and-squirt treatments without underspray were sampled. Slight declines in salmonberry cover in the controls between 1988 and 1989 may be a result of increasing shade from a denser tree canopy, but again these changes are within the range of sampling error.

Changes in forage availability after hack-and-squirt treatments are likely a function of several factors, including initial shade levels and species composition. For example, if a stand had very high alder stocking, then canopy reduction might result in a rapid increase in forage abundance. Alternatively, if the shrub layer in the stand was dominated by shade-tolerant species, then forage abundance might decline post-treatment. It appears that any increases in fruit production may not be evident until 2–3 years after treatment. Shrubs may require time to adapt to the new light regime.

A possible short-term negative impact of hack-and-squirt is that bear access into treated stands may be hindered by debris. Falling trees may also damage shrubs.

Foliar

Cover of fruit-producing shrubs and fruit abundance indices in pre-treatment and control foliar blocks were similar to that in the hack-and-squirt treatments (Figures 3 and 6; Tables 7 and 8). Although there was some variation in the severity and distribution of impacts in the 1988 treatments, results indicate a substantial loss of forage during the first year after treatment.

It appears that the higher the level of glyphosate impact to the shrub layer, the greater the magnitude of its recovery. The shrub layer on sites with the greatest apparent impacts from 1987

treatments increased the most between 1988 and 1989. However, unlike the 1987 hack-and-squirt treatments with underspray, which had high shrub cover in 1989 (~70%), the 1987 foliar treatments had an average of only 20% shrub cover by 1989. This may be less than one-third to one-half of the pre-treatment shrub cover on these sites (pre-treatment 1988 foliar blocks and the foliar controls had at least 50% shrub cover).

Division of the forage shrubs into two groups based on their known susceptibility to glyphosate was useful in explaining some of the results. The responses of Group B shrubs to treatment were more varied and less severe than for Group A shrubs (e.g., Figures 7a and 7b), and pre-treatment cover of Group B shrubs was generally far lower than for Group A.

Small sample sizes limit the usefulness of the fruit abundance and weight data. For example, red elderberry fruit production in the Phillips was the highest recorded for any species after treatment. However, the majority of these berries were on two plants: one that had been missed by the applicators, and another that had malformed leaves and berries. It is unknown if such abnormal fruit is palatable to bears.

4.1.3 Glyphosate efficacy trial

Although herbicide impacts were varied and generally patchy at all application rates in the Klinaklini trial, the most severe impacts were in the area treated with 1.42 kg a.i./ha. Differences between the lower rates were not readily apparent 1 year post-treatment. Figures 8a, 8b, and 8c (right) show that most changes in cover were within the range of sampling error (i.e., <10%).

The difference between the cover changes observed for the 1988 operational foliar treatments (macrocover difference=-41, microcover difference=-32) and those for the three macroplots treated at 1.42 kg a.i./ha in the efficacy trial (macrocover difference=-19, microcover difference=-21) are possibly explained by the difference in species composition. The Klinaklini site had a higher proportion of Group B shrub cover (predominantly red-osier dogwood) and a lower total shrub cover than the other study sites.

The highest rate used in the Klinaklini trial was less than the most common operational rates used throughout the CWH. Sixty percent of the Pesticide Use Permits for areas in the CWH propose between 2 and 2.2 kg a.i./ha. Rates less than 2 kg a.i./ha appear to be only partially effective at shrub control (this study). However, Reynolds *et al.* (1989) reports that an application rate of 1.7 kg a.i./ha is optimal for coastal weed control.

4.2 Watershed Habitat Mapping

In addition to the short-term loss of forage shown by this and other studies, glyphosate use may accelerate succession. Several studies have demonstrated that closed-canopy conifer plantations afford limited understory production (e.g., Alaback 1984; Schoonmaker and McKee 1988). Under current management practices, all logged sites must be restocked (at prescribed standards of 500–900 stems per hectare) and managed until seedlings reach the free-to-grow stage. In areas where most logging has occurred in the last 30 years, there will be a grizzly bear forage deficit.

In general terms, the impacts of glyphosate in the Chuckwalla–Kilbella watershed do not appear so severe (i.e., a 10% decline in the availability of high value habitats). However, most glyphosate use appears to be in high and medium value bear habitat. An increasing proportion of the low elevation habitats will reach the unproductive intermediate seral stages as succession proceeds. Potentially, half of the land area less than 500 ft in elevation will be unproductive grizzly bear habitat by the year 2010.

Glyphosate impacts are particularly significant when they occur on the floodplain because of the importance of these units to grizzly bears (Hamilton 1987). The loss of 12% of the high value berry feeding areas in an important unit like the FF (over just 3 years) can have consequences at the watershed level, particularly in areas of high grizzly bear density.

4.3 Forestry-related Glyphosate Use in the CWH

The summaries presented in Section 3.3 indicate that glyphosate use in mainland coastal British Columbia should be of concern to managers responsible for coastal grizzly bears and their habitat. Although the totals of area logged in occupied grizzly bear habitat are unavailable, they are likely proportionate to regional totals. On Crown land in the Vancouver and Prince Rupert Forest Regions, an average of 61 709 ha were logged annually in the 1985–86 and 1986–87 fiscal years (B.C. Ministry of Forests 1986, 1988). An average of 12 479 ha were treated annually with glyphosate in these regions (Humphries 1987, 1988, 1989), 20% of the annual timber harvest level.

5 MANAGEMENT INTERPRETATIONS AND RECOMMENDATIONS

Successful integration of grizzly bear and forest management in coastal British Columbia depends on effective communication and input to every level of forest planning. First, there should be an allowance for the maintenance of grizzly bear habitat capability at the regional level, in TSA and TFL Management and Working Plans. Identification of potential volume reductions from the Allowable Annual Cut (AAC) at this level of the planning hierarchy ensures that requests for habitat maintenance at the watershed and stand levels are "consistent with plans formulated pursuant to section 4(c) of the Ministry of Forests Act"; that is, that planning for wildlife is "coordinated and integrated" with other forest resources. As well, requests at the Local Resource Use Plan (LRUP), Five-Year Development Plan, and Pre-Harvest Silviculture Plan (PHSP) levels may include long-term deferrals, fringe provisions beside important habitats, different approaches to restocking on some sites, and minimal use of glyphosate. In addition, extended rotations may be requested to maintain grizzly bear habitat values into the future.

The objective of an integrated grizzly bear habitat and forestry system is:

> **To maintain and manage grizzly bear habitat in a condition suitable to support viable grizzly bear populations, while practising sustainable[7] forestry.**

This objective can best be met through a combination of habitat protection *and* promotion of methods that maintain habitat value after harvest. Such a system should ensure that the amount, diversity, productivity, distribution and accessibility of habitats are adequate throughout a watershed during and *after* development. Some sites would have wildlife management priority, others would be managed for multiple use. Forest level plans should include provisions for joint resource production; the objective would be to optimize both resources on carefully selected sites. However, individual resource values may be compromised on multiple use sites as it is unlikely that maximum productivity of both resources can be maintained.

Following are specific recommendations to improve integrated management:

- Planning should be site-specific but resource values should be put in context geographically, ecologically, and according to individual resource management objectives. For example, the impacts of proposed vegetation management on grizzly bear habitat should be examined in the context of habitat availability in the vicinity.
- Costs and benefits of all forest resources should be examined. For example, low volumes, uneven stocking, difficult logging, and risks of reforestation failure should preclude development on some floodplain, fan, and wetland sites in the CWH that also have high grizzly bear and fisheries values.
- Various time and spatial scales should be examined. For example, the impacts of a vegetation management program on grizzly bear habitat should be assessed on both a site-specific *and* watershed basis. The effects on habitat should be predicted for the short term and projected into the future.

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[7] Defined according to the principles of sustainable development. These involve: "1) rates of renewable resource use within the limits of regeneration and natural growth, 2) determination of maximum sustainable yield *after* taking into account the system-wide effects of exploitation, and 3) the conservation of plant and animal species" (World Commission on Environment 1987).

- The impacts of proposed timber harvest and subsequent silviculture on grizzly bear habitat should be assessed together. For example, time frames for projections of silvicultural activity should be the same as those for timber harvest in Five-Year Development Plans (i.e., 2 years confirmed).

5.1 Recommendations: Habitat Classification, Inventory and Evaluation

1) The Biogeoclimatic Ecosystem Classification (BEC) system should be used as a framework for integrated management.

Problem:

An ecological land classification and mapping system is required to identify and communicate bear habitat values. The BEC system (Pojar *et al.* 1987) can be used; new or bear-specific units and descriptions are not necessary. The BEC system is especially valuable because relating grizzly bear habitat values to forest and timber type classifications and maps is difficult. The hierarchical structure of BEC allows identification of bear habitat values at different map scales (e.g., variants at 1:500 000, site series at 1:20 000). Although large scale maps are produced for PHSP's, they cover only the commercial timber types proposed for logging; maps of entire watersheds are rare. The lowest taxon currently available in the BEC system is site association. The classification does not yet include site series, site types or plant associations that dominate the early successional stages after logging.

Pesticide Use Permit applicants are generally not required to submit ecological information to the Pesticide Control Branch. Silviculture regulations now require identification of site (ecosystem) associations on PHSP's, but there are no provisions on the permit application forms for site classification or description of the structure, age, and floristics of the sites to be treated. Unless obtained through site-specific reviews, permits are granted in the absence of ecological information about proposed treatment areas.

Solution:

Use of the BEC system in coastal British Columbia should be expanded to help achieve integrated management. The BEC system is being modified. New site association lists and revised silviculture guides will be available, and grizzly bear seasonal habitat values should be linked to the new classifications.

Proposed changes to the Pesticide Use Permit review system would provide some of the ecological information for each block. These changes should include site classification according to the BEC system. Follow-up forms should be similarly modified. This information should be included in the computer data base maintained by the Pesticide Control Branch. As further refinements of the classification become available (e.g., site types), they should be added to PHSP and Pesticide Use Permit application forms and entered in the data base.

Watersheds should be mapped with the BEC system for use in LRUP's (1:20 000 scale), Five-Year Development Plans, and PHSP's. These maps can assist the planning for roads, harvesting, silviculture and grizzly bear habitat. The extent of the potential impacts of glyphosate could also be examined on an ecological basis. Funding levels for this kind of integrated planning tool should be increased.

Tables 14, 15, and 16 should be used to determine whether there is a potential conflict between glyphosate use and grizzly bears. Grizzly bears are not uniformly distributed throughout the CWH. Table 14 identifies which ecoregions and variants are of concern. Most conflicts over glyphosate use occur on lower slopes (seepage areas), nutrient-rich wetlands, tributary creek fans, and floodplains (Table 15). In the future, it will be possible to relate bear values to site series and types; in the interim, Tables 15 and 16 can be used to identify potential conflicts on the basis of site associations.

2) The Pesticide Control Branch should require that maps of areas treated with glyphosate be submitted as part of the annual follow-up reports required under each permit.

Problem:

Maps are submitted with Pesticide Use Permits to identify areas of proposed glyphosate treatment. However, licensees seldom treat all of these areas. Applicants are required to submit annual follow-up reports indicating total area treated under each permit, but there is no information on exact location of treatment.

TABLE 14. CWH variants occupied by grizzly bears, classified by ecoregion and ecosection (B.C. Ministry of Forests 1988; B.C. Ministry of Environment 1989)

Ecoregion	Pacific and Cascade Ranges				Coastal Gap		Nass Ranges	Boundary Ranges
Ecosection	SPR	EPR	NPR	OUF	HEL	KIR		
CWHvh1					X			
CWHvh2					X			
CWHwm						X		X
CWHvm1	X	X	X	X		X		
CWHvm2	X		X	X	X[a]	X		
CWHdm[b]	X		X	X[c]				
CWHds1		X	X			X		
CWHds2			X			X		
CWHms1	X[d]	X	X					
CWHms2			X			X		
CWHws1						X	X	
CWHws2			X			X	X	

[a] Upper elevations of Johnston-Sandell rivers.
[b] Does not occur north of Loughborough Inlet.
SPR – lower Pitt R., Mamquam–Skookum rivers, mouth of Skwawka–Hunaechin rivers, mouth of Powell–Daniels rivers, lower Squamish R.
NPR – lower Toba R.
[c] Lower Phillips R. (below lake).
[d] North-flowing tributary of Ashlu R.

TABLE 15. CWH site associations (Banner *et al.* 1990) of high grizzly bear value (for variants known to be occupied by grizzly bears)

For (medium-) rich to very rich soil nutrient regimes only:

	Soil moisture regime	CWHvh (outer, inner)	CWHwm	CWHvm (submontane, montane)	CWHdm	CWHds (southern, central)	CWHms (southern, central)	CWHws (submontane, montane)
	Fresh	CwSs-Sword fern	SsHw-Oak fern	BaCw-Foamflower	Cw-Foamflower	Cw-Solomon's seal	BaCW-Oak fern	
	Moist	CwSs-Foamflower	SsHw-Devil's club	BaCw-Salmonberry[a] BaSs-Devil's club[b]	Cw-Lady fern	Cw-Devil's club	BaCw-Devil's club	
	Very Moist	CwSs-Devil's club						
	Wet	CwSs-Skunk cabbage	Ss-Skunk cabbage	CwSs-Skunk cabbage				
Floodplain	high bench	Ss-Lily-of-the-valley	Ss-Salmonberry					
Floodplain	medium bench	Ss-Trisetum	Ac-Red-osier dogwood					
Floodplain	low bench	Dr-Lily-of-the-valley	Ac-Willow					

[a] In the southern portion of the CWHvm.
[b] In the northern portion of the CWHvm.

TABLE 16. Impacts of silviculture on grizzly bear forage production, by soil moisture regime[a]

Soil nutrient regime	Description
Fresh	May produce abundant fruit shortly after logging (particularly red elderberry and red raspberry). Blueberries (*Vaccinium* spp.) and red huckleberries (*V. parvifolium*) may be available, particularly in shaded areas of cutovers. Depending on treatment severity, these site associations may recover shrub fruit productivity 3–4 years after glyphosate treatment. However, as the coniferous canopy develops, shrub cover declines to near zero (Schoonmaker and McKee 1988). Fresh sites have lower forage value per unit area than moister ecosystems. However, the loss of *Vaccinium* berry feeding areas could be significant on a watershed basis (e.g., as might result from high rates-of-cut followed by intensive silviculture).
Moist and Very Moist	May produce abundant forage. Shade-tolerant berry species found in mature forest understory (e.g., Devil's club) may be replaced after logging by shade-intolerant species like red raspberry. Red elderberry, salmonberry, currants and red-osier dogwood may also be important foods after logging. Early and late seral stages of these site associations are more valuable habitats than the middle seral stages except when a deciduous canopy develops. Many of the backlog reforestation areas throughout the CWH are alder-dominated stands on these sites. Fruit production under a pole-sapling to young seral deciduous canopy may be high (e.g., salmonberry, red elderberry). Conifer-dominated intermediate seral stages, especially well-stocked plantations, lack productive understories; few food plants are present under closed-canopy second growth (Alaback 1982).
Wet	Major concern because of high forage values in most seasons and seral stages. Only some fruit-producing shrubs are able to tolerate fluctuating water tables on these sites (e.g., salmonberry). Other species grow on organic mounds or at the base of stumps and trees (e.g., red huckleberry). Ecotones and drier microsites may have higher shrub cover and fruit production than the rest of the site. The nature of these site associations apparently prevents closed-canopy, conifer-dominated second growth; plantable sites are limited by the water table. Also, amount of surface water often limits use of glyphosate.
Floodplain	Highest value berry feeding habitats in the CWH. Twelve of 16 berry species used by coastal grizzly bears thrive in floodplain habitats. Fruit availability in intermediate seral stages is inversely related to stocking and vigour of conifers. As for fresh, moist and very moist sites, high and medium bench floodplain site associations lack forage under closed-canopy conifer plantations (Alaback 1984). However, extreme difficulty of restocking floodplains with conifers makes this less of a concern; floodplain not satisfactorily restocked (NSR) areas may function as productive bear habitat.

[a] Site associations (Table 15) within a soil moisture regime respond similarly to treatment, however, differences can be expected across subzones.

Furthermore, there is no means of determining glyphosate treatment history within the current pesticide referral system. Repeated treatments on floodplain sites appear to be common, but information is available only from the Ministry of Forests or from licensee stand-tending records. A history of glyphosate treatment on a site or in the vicinity of a proposed treatment could influence grizzly bear habitat concerns.

Solution:

The Pesticide Control Branch should require that maps of areas treated be part of the annual Pesticide Use Permit follow-up reports. A set of up-to-date herbicide history maps, complete with information on rates, treatment dates and methods, should be available during Five-Year Development Plan field tours. Licensees using a GIS should consider entering glyphosate treatments as a map level. Summary of areas treated would be simple and impacts of glyphosate on grizzly bear habitat could be examined by watershed.

3) Whenever possible, field evaluation of potential impacts of glyphosate should be conducted twice: First, during the Five-Year Development Plan field tour, and as input to the PHSP for the cutting unit; and second, after logging as part of the pesticide referral process.

Problem:

Recommendations for grizzly bear habitat maintenance depend on such a wide variety of factors that we cannot provide rigid guidelines. Grizzly bear habitat values assigned on a "type" basis alone (e.g., Appendix 3) lack information about landscape diversity, size, proximity to other habitats and roads, and within-stand

variation. Unfortunately, field checks cannot always be conducted because of travel and access difficulties and staffing shortages.

As well, vegetative competition and forage availability after logging are not easily predicted. There is little published information on post-logging succession in the CWH zone.

The potential for repeated herbicide treatment is not currently identified in the PHSP. Some evidence indicates that repeated glyphosate application will change the species composition of a site. Less biomass and fewer bear forage species may result after the second treatment. Repeated treatments also shorten the length of time forage is available after logging.

Solution:

Field checks should be conducted by Fish and Wildlife Branch staff during Five-Year Development Plan tours. Sites to visit should be chosen by priority, according to Tables 15 and 16. Both applications forwarded by the Pesticide Control Branch for comment and proposed PHSP's should provide wildlife biologists with enough information to assess whether bear habitat protection or maintenance is a concern.

The evaluation of a potential treatment should consider habitat changes over time. Past, present, and future use and availability of resources should be assessed. Prescriptions must be flexible so that if post-logging site conditions vary from those predicted, alternative measures could be adopted to maintain bear values (while ensuring timber production).

The possible need for repeated herbicide treatments (including site preparation with glyphosate) should also be identified in the PHSP.

The intent of the PHSP is to "bring about at the end of the logging process: 1) those conditions on the harvested area that will have best preserved the inherent site productivity and which will give rise to the establishment of a new stand best suited to the site for both volume and value production, and 2) **those conditions which have protected, or preserved the opportunity to manage for, other natural resources**" (B.C. Ministry of Forests 1987). At present the Ministry of Environment uses PHSP's as information sources only. Comments on silviculture prescriptions are made as part of the Five-Year Planning Process. Fish and Wildlife Branch staff expect that concerns raised in Five-Year Planning are reflected in PHSPs. Informed, site-specific grizzly bear habitat provisions should be developed and integrated with silviculture planning systems regardless of how background information is gathered and herbicide impacts on habitat are predicted.

The following questions could be used in the evaluation of a proposed herbicide treatment:[8]

1. What grizzly bear resources are present *before* logging? That is, what forage species are present and what are their productivity levels?
2. Is the site heavily used by grizzly bears?
3. Will logging affect the supply of grizzly bear resources?
4. Will the original values be maintained, be replaced, or decline after logging? That is, what resources is the site capable of producing? Will the availability of these resources change during succession?

"Patch" habitat value based on size and location (e.g., proximity to important habitats such as skunk cabbage swamps, avalanche chutes, estuaries, salmon spawning areas, non-forested wetlands) should be considered during the assessment. Permanent bear sign (e.g., mark trees), recent sightings, scats, beds, trails, and feeding sign (e.g., broken red elderberry branches, disturbed red raspberry canes, umbel digging) will assist the evaluation. Adjacent habitats should also be examined to help put the proposed treatment in the context of grizzly bear resources in the vicinity.

Prediction of the potential impacts of a herbicide treatment should include an assessment of:

1. the susceptibility of the forage species present to glyphosate;

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[8] If the site has already been logged, the same questions can be answered (e.g., What grizzly bear resources *were* present before logging?).

2. the size of the proposed treatment;3. the availability of equivalent alternative habitats in the vicinity;
4. the likelihood of silvicultural success; and
5. the probability of maintaining current resource productivity with and without treatment.

Again, the proposed treatment should be examined in relation to future harvesting plans.

5.2 Recommendations: Operations

1) Consideration should be given to relaxing stocking standards to maintain an open canopy throughout the rotation, where fruit-producing habitats are, or will be, in short supply. Alternatively, stocking standards could be met, but the stands left unlogged past the usual rotation age.

Problem:

Coastal grizzly bears require a large amount of fruit to meet their annual forage requirements. In a managed forest, the supply of fruit and other bear forage is potentially limited if 25- to 80-year-old conifer-dominated plantations cover a high proportion of the landscape.

The use of glyphosate to meet free-to-grow requirements can turn recently logged (shrub-dominated) sites into unproductive bear forage areas. Although it appears that fruit production may recover, at least in part, within 2–3 years after foliar applications, re-treatment may be prescribed. Retreated sites will likely have little forage available. Glyphosate treatment of shrub-dominated cutovers and deciduous-dominated plantations accelerates succession and canopy closure on these sites, reducing the length of time that bear forage is available. Second-growth stands that meet regional stocking standards (e.g., 500–900 stems per hectare at 8–11 years of age) will have limited fruit production 25–30 years after logging. Even on the richest floodplain sites, little forage will be available for over half of the rotation on sites that meet minimum or higher stocking standards.

Juvenile spacing (pre-commercial thinning) and pruning would, ideally, open the canopy sufficiently to encourage the growth of fruit-producing shrubs. However, there is little evidence that demonstrates the long-term effectiveness of early spacing on moist to wet and floodplain site associations in the CWH. Recovery of understory productivity has been recorded in some studies, but diversity and biomass increases are short-lived (Alaback and Herman 1988). As the canopy re-closes, forage availability will again decline. Repeated spacing would probably not be cost-effective. Furthermore, debris left in the stand might hinder bear access to whatever fruit is produced.

Commercial thinning may also not be appropriate as a means of maintaining forage production. Studies on western hemlock (*Tsuga heterophylla*) indicate there is little economic incentive for commercial thinning because volumes do not increase appreciably (Omule 1988). Many sites cannot be thinned because they are too steep or too wet for skidders. Horse logging or skyline systems may be possible but not economic. Bear forage species may be limited in their ability to recolonize a thinned stand. Viable rhizomes do not survive the depauperate understory stage; regrowth of shrubs would have to come from a 40- to 60-year-old seed bank or from animal-dispersed seeds. The soil must be disturbed to stimulate the seed bank and adequate light must be available so that the understory can recover to former levels and maintain habitat value for the remainder of the rotation.

Conflicts with timber management objectives can result if wider spacing is required to maintain fruit production. Trees grown in open stands may be of lower quality because of their many large and gnarled branches. Recommendations to relax stem densities could affect the balance between silvicultural costs and future timber benefits, particularly if the objectives for the site are to maximize volume rather than piece size (Pollack *et al.* 1990). Existing standards are chosen to maximize production; optimal stands for timber are neither too dense nor too open.

Solution:

There is an obvious relationship between conifer stocking density and fruit production. Depending on expected conditions, an integrated option for *some sites* may be the harvest of old-growth timber. Instead of meeting the stocking standards on the entire block, however, the District Manager could allow a partial

exemption from this requirement. Foresters and wildlife biologists could design a tree planting layout with gaps large enough to remain relatively open through succession. These gaps could be left to regenerate naturally to provide wildlife forage. All but the early pole-sapling stage of the natural succession—when the gaps may be dominated by alder or cottonwood—would provide grizzly bear forage. A management option could include girdling of the deciduous trees if the canopy is too dense to maintain fruit production. Otherwise, the stand would eventually self-thin and the canopy reopen. Recovery of shrub understories after deciduous overstory removal was demonstrated in this study and by Coates *et al.*[9] When gaps have been identified, other sites within the stand (e.g., areas close to existing roads, drier sites) would have timber production priority and be managed according to regional stocking standards.

Group selection could be used to create similar "gaps" at the harvesting stage. However, the economic or ecological feasibility of group selection has not been investigated in coastal British Columbia.

A blanket recommendation for lowering regional stocking standards to ensure fruit production throughout the rotation is not appropriate at this time. It may be possible to produce economic tree crops in uniformly spaced stands open enough to ensure fruit production, but current information is inadequate. If planting densities were lowered, glyphosate could be used to reduce competition, applied only to the area immediately surrounding each seedling. However, such prescriptions are premature until further data are available. A preliminary study designed to investigate the effects of variable spacing is being conducted in the Kimsquit and Kilbella valleys.[10]

The key to ensuring a supply of grizzly bear habitat in a managed forest is to maintain habitat diversity across the landscape and within habitat patches. Extended rotation should be considered when expected future conditions indicate a shortage of fruit-producing habitats as a result of extensive clearcut logging followed by intensive silviculture. Priority should be given to stands with the highest forage potential: moist and very moist, wet, and floodplain site associations. As a plantation matures beyond 150 years, shade-tolerant species gradually recolonize the site and provide bear forage. Gaps develop in the overstory and allow other forage species to invade (Alaback 1984).

2) On sites with potential conflicts between grizzly bear habitat objectives and the use of glyphosate, consideration should be given to alternative silvicultural techniques.

Problem:

Rich sites in the CWH zone are extremely difficult to regenerate. In the past, because of a lack of information, tree species chosen for regenerating these sites did not follow principles of productivity, reliability, and feasibility (Klinka and Feller 1984). Even repeated glyphosate use is not always successful in establishing a free-growing crop of commercial tree species.

Some regeneration techniques that do not include use of glyphosate or other herbicides may have equal or greater impacts on grizzly bear forage availability. For example, preliminary results from a study on various alternative silvicultural methods for the conversion of red alder stands to conifer plantations indicate that treatments which include blading severely affect forage potential on the site—especially when combined with grass seeding.[11]

Solution:

Managers should have at their disposal "a variety of vegetation management tools and techniques to maximize flexibility and increase the ability to match the treatment to the situation" (Walstad 1988). The impacts on grizzly bear forage supply should be considered before any vegetation management technique is chosen.

For example, more emphasis is being put on hardwood management on floodplain site associations in the CWH. Large areas of NSR could be converted to productive cottonwood and alder plantations. Mixed

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[9] Coates *et al.*, 1990.

[10] Hamilton, A.N. 1990. Alternate regeneration systems on floodplain sites in the CWH. Preliminary trials of integrated resource management options: Kimsquit and Kilbella rivers. Draft project proposal. B.C. Min. Environ., Wildl. Branch, Victoria, B.C.

[11] Coates *et al.*, 1990.

hardwood and softwood stands also have economic potential (e.g., regeneration of Sitka spruce under cottonwood). However, such regeneration systems may depend on high stocking, glyphosate use, and short rotations. Lower stocking and longer rotations than might be ideal from a timber management standpoint may be necessary to maintain fruit availability.

There is evidence that manual (e.g., brush saws) or mechanical (e.g., Hydroaxe) cutting to control competing shrubs may not be cost-effective.[12] However, if only 1 year of control is required, cutting may be appropriate. Impacts on bear forage are lessened because species diversity and productivity are not affected to the same degree as with glyphosate treatments.

Girdling hardwoods appears to favour bear forage availability as do hack-and-squirt treatments.[13] A girdled stand may retain a partial canopy 1 year after treatment, possibly enhancing fruit production more than a hack-and-squirt treatment would. Further information on the possible benefits of girdling is not yet available.

3) The minimum amount of glyphosate required to meet silvicultural obligations should be used. Managers should be selective about which sites to treat and where to treat within them.

Problem:

Evidence from this and other studies indicates there are many factors influencing the effectiveness of broadcast treatments. Impacts are often varied, particularly with aerial spraying. Some applications are more effective at reducing vegetative competition than others and consequently have a greater impact on grizzly bear habitat capability. This variability makes it difficult to forecast impacts and prescribe appropriate mitigative techniques.

The cost-effectiveness of broadcast methods is obvious. Requiring managers to be selective of "targets" and target areas will increase treatment costs. As well, selective applications are not possible on some sites because of restricted access and the difficulty for workers to find conifer seedlings in extremely thick vegetation.

Solution:

When a conflict arises between bear habitat value and the need for foliar glyphosate application, impacts may be minimized in several ways:

- Applicators can be instructed to treat specified competitors only (e.g., alder and cottonwood).
- Backpack and clear-saw methods can be used to treat only those shrubs directly competing with conifer seedlings. Where this is inappropriate (e.g., 100% cover of 2 m tall salmonberry), a "selective" aerial or powerhose treatment could be achieved, in which a minimum area within the plantation is treated (e.g., gaps in the conifer distribution are not sprayed).
- Competing shrubs have different forage values. If selective treatment is an option, the highest value forage should be left untreated. The following shrub species are listed in descending order of value as grizzly bear forage:

  Red elderberry
  Red raspberry
  Salmonberry
  Vaccinium spp.
  Ribes spp.
  Black twinberry
  Highbush-cranberry
  Red-osier dogwood
  Thimbleberry

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[12] D'Anjou, 1989.
[13] Coates *et al.*, 1990. Section 3.1.1.

Skunk cabbage (*Lysichiton americanum*), lady-fern, cow-parsnip (*Heracleum sphondylium*), white angelica (*Angelica genuflexa*), water-parsley (*Oenanthe sarmentosa*), and hemlock-parsley (*Conioselinum* spp.) should also be avoided. Selective treatment is consistent with the Ministry of Forests Silviculture Manual (1987, Volume III, Chapter 12, Section 12).

- Application rates and timing can be varied to lessen the impact on some forage species. It may be possible to achieve "control" by killing only the above-ground foliage, not the entire plant. This speeds forage recovery, without creating growing space for other, non-forage species. Detailed information about the species composition on a site could be combined with information on species-specific responses to help managers prescribe a treatment that affects forage only minimally, but fulfills silvicultural objectives.

4) The need for glyphosate use can be reduced if site disturbance is minimized.

Problem:

On rich sites in the CWH, the greater the site disturbance, the more severe the vegetative competition.[14] Several species propagate vegetatively (e.g., black cottonwood, red-osier dogwood) and could quickly dominate a site after canopy removal if they are broken up and spread around. In addition, site disturbance may create seedbeds ideal for the germination of airborne seed.[15] While high levels of disturbance may result in more forage than would be available with sensitive harvesting, the forest management objective to regenerate these sites may require greater herbicide use. An "integrated" solution is not likely possible.

Solution:

Managers should use all possible methods to discourage severe vegetative competition. Careful harvesting may preclude the need for glyphosate use, lessening the impact on grizzly bear forage availability.

5) Roadside spraying should be minimized beside high value open habitats to allow a visual screen for grizzly bears to grow.

Problem:

A major logging impact on grizzly bears is the result of the increased access that logging creates for legal and illegal hunters. Hunters have easy access to bears when logging roads are located beside concentrated food sources such as sedge fens, avalanche chutes, and spawning channels. On sites with equal levels of human use, bear vulnerability is proportionate to bear visibility.

Visual screens beside valuable habitats should be discussed during harvest planning. Such screens can be maintained by the removal of only the commercial timber from a 15-m buffer, leaving the non-merchantable trees and shrub layer intact. If such a buffer is not present, however, the use of glyphosate might remove the only cover adjacent to the road.

Solution:

All provisions for visual screening should be made after site-specific information on grizzly bear use has been considered. Overriding the need to provide cover is the maintenance of safe road networks.

Two types of visual screens are recommended along active roads:

- *Temporary visual screens* should be considered where recent logging has created an opening with high visibility beside a valuable feeding habitat. A temporary 10- to 15-m herbicide-free roadside buffer could be provided until the cutover closes in with conifers or a vigorous shrub layer. A temporary screen would delay regeneration only 2–3 years on a minimal area.
- *Permanent visual screens* or herbicide-free buffers should be considered where bears are attracted to area-concentrated food sources, such as spawning salmon, in naturally open habitats adjacent to roads. This is particularly important where no provision for screening was made during harvesting.

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[14] See, for example, Coates *et al.*, 1990.
[15] Coates *et al.*, 1990.

6 RESEARCH RECOMMENDATIONS

1. Forestry development is now taking place in the Mountain Hemlock (MH) zone (Scagel and Evans 1989). However, there is little information on bear values or glyphosate impacts, on which integrated management decisions can be based. More research into grizzly bear habitat values and the potential impacts of vegetation management should be conducted. Although vegetative competition is less of a concern in the MH than at low elevations (Scagel and Evans 1989), the use of glyphosate to create plantable areas may reduce bear forage availability.
2. Current efforts should continue in developing a post-logging (secondary succession) classification for the CWH, and predictive models to go with it. Bear habitat values could be described for each vegetation complex or seral association, potential conflicts identified, and appropriate prescriptions recommended.
3. The relationships between juvenile spacing, canopy closure, and understory productivity and diversity should be examined on rich sites in the CWH. Although preliminary studies indicate otherwise, economically viable, integrated solutions may yet be possible. Similar information should be obtained for hardwood plantations. Stocking levels and rotation lengths that maximize cottonwood and alder production *and* forage availability should be determined.
4. As techniques for monitoring the impacts of operational glyphosate treatments are refined (e.g., Hatler 1989; Lloyd[16]; Hays[17]), consideration should be given to developing monitoring methods specific to bears. Better indices of fruit abundance and more objective means of determining bear use are required.
5. Further rate and timing trials with glyphosate should be conducted, specifically on grizzly bear forage species. It may be possible, for example, to treat sites where alder and cottonwood are the major competitors during periods, or at concentrations, that have minimal impact on important forage species.
6. Research should continue into alternative silvicultural techniques for rich sites throughout the CWH. Emphasis should be put on ecological suitability, practicality, economics, and the integration of wildlife values.
7. Sites sampled in this study should be resampled within 5 years.

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[17] Hays, W.J. 1990. Operational herbicide monitoring in the Prince George Forest Region. B.C. Min. For., Prince George, B.C. Unpublished manuscript.

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APPENDIX 1. Plant species list from 1988 and 1989 field seasons in the Phillips, Chuckwalla, Kilbella, Kingcome, and Klinaklini watersheds. Boldface indicates the fruit-producing shrub species fed on by coastal grizzly bears (Hamilton 1987).

Species code	Scientific name	Common name
ABIEAMA	*Abies amabilis*	amabilis fir
ACHIMIL	*Achillea millefolium*	yarrow
ACTARUB	*Actaea rubra*	baneberry
ADIAPED	*Adiantum pedatum*	maidenhair fern
AGROSCA	*Agrostis scabra*	hair bentgrass
AGROSTI	*Agrostis* sp.	
ALNURUB	*Alnus rubra*	red alder
ANAPMAR	*Anaphalis margaritacea*	pearly everlasting
ARUNDIO	*Aruncus dioicus*	goatsbeard
ASTER	*Aster* sp.	
ATHYFIL	*Athyrium filix-femina*	lady fern
BLECSPI	*Blechnum spicant*	deer fern
CALACAN	*Calamagrostis canadensis*	bluejoint
CALAMAG	*Calamagrostis* sp.	
CARECAN	*Carex canescens*	grey sedge
CAREMER	*Carex mertensii*	Mertens' sedge
CAREX	*Carex* sp.	
CINNLAT	*Cinna latifolia*	nodding wood-reed
CIRCALP	*Circaea alpina*	enchanter's nightshade
CIRSIUM	*Cirsium* sp.	
CIRSVUL	*Cirsium vulgare*	bull thistle
CLAYSIB	*Claytonia sibirica*	Siberian miner's-lettuce
CLINUNI	*Clintonia uniflora*	queen's cup
COPTASP	*Coptis asplenifolia*	fern-leaved goldthread
CORNCAN	*Cornus canadensis*	bunchberry
CORNSER	***Cornus sericea***	**red-osier dogwood**
CYSTFRA	*Cystopteris fragilis*	fragile fern
DICEFOR	*Dicentra formosa*	bleeding heart
DISPHOO	*Disporum hookeri*	Hooker's fairybells
DISPTRA	*Disporum trachycarpum*	rough-fruited fairybells
DISTICH	*Distichlis* sp.	salt grass
DRYOASS	*Dryopteris assimilis*	spiny wood fern
ELYMGLA	*Elymus glaucus*	blue wildrye
EPILANG	*Epilobium angustifolium*	fireweed
EPILGLA	*Epilobium glandulosum*	sticky willowherb
EQUIARV	*Equisetum arvense*	common horsetail
EQUIHYE	*Equisetum hyemale*	scouring-rush
EQUITEL	*Equisetum telmateia*	giant horsetail
ERIGPHI	*Erigeron philadelphicus*	Philadelphia fleabane
ERYTGRA	*Erythronium grandiflorum*	glacier lily
FESTOCC	*Festuca occidentalis*	western fescue
FESTRUB	*Festuca rubra*	red fescue
FESTSUB	*Festuca subulata*	bearded fescue
FESTUCA	*Festuca* sp.	
FRAGVES	*Fragaria vesca*	wood strawberry
FRAGVIR	*Fragaria virginiana*	wild strawberry

APPENDIX 1. (Continued)

Species code	Scientific name	Common name
GALIKAM	*Galium kamtschaticum*	boreal bedstraw
GALITRF	*Galium triflorum*	sweet-scented bedstraw
GALITRI	*Galium trifidum*	small bedstraw
GEUMMAC	*Geum macrophyllum*	large-leaved avens
GYMNDRY	*Gymnocarpium dryopteris*	oak fern
HERASPH	*Heracleum sphondylium*	cow-parsnip
HIERALB	*Hieracium albiflorum*	white-flowered hawkweed
LIGUSTI	*Ligusticum* sp.	lovage
LONIINV	***Lonicera involucrata***	**black twinberry**
LUZUPAR	*Luzula parviflora*	small-flowered woodrush
LUZUSPI	*Luzula spicata*	spiked woodrush
LYSIAME	*Lysichiton americanum*	skunk cabbage
MAIADIL	*Maianthemum dilatatum*	false lily-of-the-valley
MALUFUS	*Malus fusca*	Pacific crab apple
MENZFER	*Menziesia ferruginea*	false azalea
MIMUGUT	*Mimulus guttatus*	yellow monkey-flower
MIMULEW	*Mimulus lewisii*	pink monkey-flower
MITELLA	*Mitella* sp.	mitrewort
MYCEMUR	*Mycelis muralis*	wall-lettuce
OENASAR	*Oenanthe sarmentosa*	water-parsley
OPLOHOR	***Oplopanax horridus***	**devil's club**
ORTHSEC	*Orthilia secunda*	one-sided wintergreen
OSMOCHI	*Osmorhiza chilensis*	mountain sweet-cicely
PICESIT	*Picea sitchensis*	Sitka spruce
POA	*Poa* sp.	bluegrass
POA PAL	*Poa palustris*	fowl bluegrass
POLYBRA	*Polystichum braunii*	Braun's holly fern
POLYGLY	*Polypodium glycyrrhiza*	licorice fern
POLYLON	*Polystichum lonchitis*	mountain holly fern
POLYMUN	*Polystichum munitum*	sword fern
POPUBAL	*Populus balsamifera* var. *trichocarpa*	black cottonwood
PRUNVUL	*Prunella vulgaris*	self-heal
PSEUMEN	*Pseudotsuga menziesii*	Douglas-fir
PYROASA	*Pyrola asarifolia*	pink wintergreen
RANUNCU	*Ranunculus* sp.	buttercup
RANUOCC	*Ranunculus occidentalis*	western buttercup
RIBEBRA	***Ribes bracteosum***	**stink currant**
RIBELAX	***Ribes laxiflorum***	**trailing black currant**
ROSANUT	*Rosa nutkana*	Nootka rose
RUBUIDA	***Rubus idaeus***	**red raspberry**
RUBULEU	***Rubus leucodermis***	**black raspberry**
RUBUPAR	***Rubus parviflorus***	**thimbleberry**
RUBUPED	*Rubus pedatus*	five-leaved bramble
RUBUSPE	***Rubus spectabilis***	**salmonberry**
SALISIT	*Salix sitchensis*	Sitka willow
SAMBRAC	***Sambucus racemosa***	**red elderberry**
SAXIFER	*Saxifraga ferruginea*	Alaska saxifrage
SCIRMIC	*Scirpus microcarpus*	small-flowered bulrush
SMILRAC	*Smilacina racemosa*	false Solomon's-seal

APPENDIX 1. (Continued)

Species code	Scientific name	Common name
SMILSTE	*Smilacina stellata*	star-flowered false Solomon's-seal
SONCHUS	*Sonchus* sp.	sow-thistle
SPIRDOU	*Spiraea douglasii*	hardhack
STACCOO	*Stachys cooleyae*	Cooley's hedge-nettle
STELCAL	*Stellaria calycantha*	northern starwort
STELCRI	*Stellaria crispa*	crisp starwort
STELLAR	*Stellaria* sp.	starwort
STELLON	*Stellaria longifolia*	long-leaved starwort
STREAMP	*Streptopus amplexifolius*	clasping twistedstalk
STREROS	*Streptopus roseus*	rosy twistedstalk
TARAOFF	*Taraxacum officinale*	common dandelion
TELLGRA	*Tellima grandiflora*	tall fringecup
THELPHE	*Thelypteris phegopteris*	beech fern
THUJPLI	*Thuja plicata*	western redcedar
TIARLAC	*Tiarella laciniata*	cut-leaved foamflower
TIARTRI	*Tiarella trifoliata*	three-leaved foamflower
TIARUNI	*Tiarella unifoliata*	one-leaved foamflower
TOLMMEN	*Tolmiea menziesii*	piggy-back plant
TRAUCAR	*Trautvetteria caroliniensis*	false bugbane
TRISCER	*Trisetum cernuum*	nodding trisetum
TSUGHET	*Tsuga heterophylla*	western hemlock
VACCALA	***Vaccinium alaskaense***	**Alaskan blueberry**
VACCINI	***Vaccinium* sp.**	**blueberry**
VACCOVA	***Vaccinium ovalifolium***	**oval-leaved blueberry**
VACCPAR	***Vaccinium parvifolium***	**red huckleberry**
VALESIT	*Valeriana sitchensis*	Sitka valerian
VIBUEDU	***Viburnum edule***	**highbush-cranberry**
VIOLGLA	*Viola glabella*	stream violet
Not present on study sites:		
VACCMEM	***Vaccinium membranaceum***	**black huckleberry**

APPENDIX 2. Definitions of habitat units and successional stages

Habitat Units

Avalanche Chute (AV) – Slopes subject to repeated avalanching. Dominated by shrubby or herbaceous vegetation. Major plant species are Sitka alder (*Alnus viridis* ssp. *sinuata*), salmonberry, stink currant, red elderberry, lady fern, spiny wood fern, rosy twistedstalk (*Streptopus roseus*), and cow-parsnip.

Cedar Seepage Forest (CS) – Lower slopes, often receiving seepage from upslope, with rich soils and well-developed humus layers. Stands are typically open and patchy mixed Sitka spruce, western redcedar, and western hemlock. Other characteristic species are devil's club, salmonberry, stink currant, red elderberry, skunk cabbage, oak fern (*Gymnocarpium dryopteris*), three-leaved foamflower, spiny wood fern, enchanter's nightshade, and lady fern. Skunk cabbage may be extremely vigorous, reaching over 1 m in height.

Estuary (ES) – Plant communities follow a gradient of tidewater influence. Vegetation closest to open water is the least diverse. Where the estuary is flooded daily, Lyngby's sedge (*Carex lyngbyei*) and tufted hairgrass (*Deschampsia cespitosa*) are characteristic. Further from tidal action, Pacific silverweed (*Potentilla anserina*), Alaska plantain (*Plantago* spp.), and Douglas' aster (*Aster subspicatus*) are common. Closest to upland sites is a fringe of shrub thickets dominated by Sitka willow (*Salix sitchensis*), black twinberry, and Pacific crabapple (*Malus fusca*).

Floodplain/Fan (FF) – Includes the active fluvial landscape composed of level, sandy soils (floodplain) and gentle to moderately sloping gravelly to cobbly soils (fans). A range of successional stages is found, including bare gravel bars, shrub thickets, young deciduous stands, and patchy old-growth stands. Tree species include red alder, black cottonwood, Sitka spruce, western hemlock, western redcedar (*Thuja plicata*), and amabilis fir (*Abies amabilis*). Common shrubs are devil's club, salmonberry, red-osier dogwood, stink currant, red elderberry, and willow (*Salix* spp). Herbs include lady fern, rosy twistedstalk, clasping twistedstalk (*Streptopus amplexifolius*), spiny wood fern, oak fern, enchanter's nightshade, three-leaved foamflower, and common horsetail (*Equisetum arvense*).

Hemlock–Blueberry Forest (HB) – Typical mid-slope upland habitat occurring throughout the CWHvm. Soils are usually deep, medium textured and well drained. The well-developed tree canopy consists of western hemlock, amabilis fir, and Sitka spruce. The continuous vigorous shrub layer is dominated by Alaskan blueberry (*Vaccinium alaskaense*) with minor amounts of oval-leaved blueberry (*V. ovalifolium*), false azalea, and red huckleberry. Cordilleran bunchberry (*Cornus unalaschkensis*), five-leaved bramble (*Rubus pedatus*), and queen's cup (*Clintonia uniflora*) are typical in the sparse, patchy herb layer.

Hemlock–Moss Forest (HM) – Shallow soil over rock hummocks and slopes is typical. Sites are generally well to rapidly drained and relatively dry. Open tree canopies are composed of western hemlock, western redcedar, and occasional amabilis fir. Other common plants include Alaskan blueberry, false azalea (*Menziesia ferruginea*), red huckleberry, twinflower (*Linnea borealis*), and Cordilleran bunchberry. A robust, continuous moss layer is usually present.

Rock Outcrop (RO) – Steep and hummocky pure bedrock terrain. Vegetation limited to occasional stunted trees and shrubs with low moss and lichen ground cover.

Rock/Talus (RT) – High elevation barren areas dominated by rock, snow, ice and low windswept scrub vegetation.

Subalpine Forest (SF) – Incorporates all forested and parkland habitat in the Mountain Hemlock Zone (above 600 m). Common trees are mountain hemlock (*Tsuga mertensiana*), amabilis fir, and yellow-cedar (*Chamaecyparis nootkatensis*). A continuous shrub layer dominated by Alaskan blueberry, oval-leaved blueberry, and copperbush (*Cladothamnus pyroliflorus*) is typical. Characteristic herbs include deer fern (*Blechnum spicant*), fern-leaved goldthread (*Coptis asplenifolia*), Cordilleran bunchberry, and five-leaved bramble.

APPENDIX 2. (Continued)

Wetland (WE) – Very diverse. Occurs on parts of the floodplain and slopes where moisture input exceeds output. Trees are usually lacking and shrubs are restricted to occasional or perimeter occurrence of stink currant, salmonberry, hardhack (*Spirea douglasii*), willow, and oval-leaved blueberry. Common herbs (any of which may dominate) include small-flowered bulrush (*Scirpus microcarpus*), skunk cabbage, bluejoint (*Calamagrostis canadensis*), lady fern, Mexican hedge-nettle (*Stachys mexicana*), sedge (*Carex* spp.), and cotton-grass (*Eriophorum* spp.).

Successional Stages

1. **Non-vegetated** – Initial stage in primary or secondary succession. Little or no residual vegetation except for bryophytes or lichen.
2. **Herb** – Early successional stage or disclimax dominated by herbaceous vegetation. Some invading or residual shrubs and trees may be present (less than 30%).

   Shrub – Early successional stage or disclimax dominated by shrubby vegetation. Tree cover less than 30% but seedlings and advanced regeneration may be abundant.
3. **Pole-sapling** – Stands composed of young trees extending into tall shrub layer (>2 m). Crown cover exceeds 30%. Age generally less than 40 years. Understories may become poorly developed as canopy closure increases.
4. **Young Forest** – Forty- to 80-year-old stands dominated by climax (shade-tolerant) or seral trees. Stands are even- or uneven-aged depending on site history.
5. **Mature Forest** – Eighty- to 250-year-old stands usually composed of climax tree species (or seral trees at earlier stage). Stands are usually uneven-aged and structurally heterogenous.
6. **Old Growth** – Very old (>250 years), all-aged, structurally complex stands composed mainly of climax trees (may be old seral tree remnants).

APPENDIX 3. Bear value ratings for habitat types (Table 2) for five seasons of use (Table 3)

Commercial habitat types – pre-glyphosate treatment (X) and up to 3 years post-glyphosate treatment (X̲):

Season	Rating	HM1	HM2	HM3D	HM3C	HM4D	HM4C	HM5	HM6
	M			X		X			
1	L					X̲		X	X
	nil	X	XX̲	X̲	X		X		
2	L			X		X		X	X
	nil	X	XX̲	X̲	X	X̲	X		
	M			X		X			
3	L			X̲[a]		X̲[a]		X	X
	nil	X	XX̲	X̲[b]	X	X̲[b]	X		
4	L			X		X		X	X
	nil	X	XX̲	X̲	X	X̲	X		
5	nil	X	X	X	X	X	X	X	X
		HB1	HB2	HB3D	HB3C	HB4D	HB4C	HB5	HB6
	M			X		X			
1	L					X̲		X	X
	nil	X	XX̲	X̲	X		X		
2	L			X		X		X	X
	nil	X	XX̲	X̲	X	X̲	X		
	M		X	X		X		X	X
3	L			X̲[a]		X̲[a]			
	nil	X	X̲	X̲[b]	X	X̲[b]	X		
4	L		X	X		X		X	X
	nil	X	X̲	X̲	X	X̲	X		
5	nil	X	X	X	X	X	X	X	X
		CS1	CS2	CS3D	CS3C	CS4D	CS4C	CS5	CS6
	H							X	X
1	M			X		X			
	L		X			X̲	X		
	nil	X	X̲	X̲	X				
	M							X	X
2	L		X	X		X	X		
	nil	X	X̲	X̲	X	X̲			
	M		X	X		X		X	X
3	L			X̲[a]		X̲[a]			
	nil	X	X̲	X̲[b]	X	X̲[b]	X		
	M							X	X
4[c]	L		X	X		X	X		
	nil	X	X̲	X̲	X	X̲			
5	nil	X	X	X	X	X	X	X	X

APPENDIX 3. (Continued)

Season	Rating	FF1	natFF2[d]	logFF2	natFF3D	logFF3D	logFF3C	natFF4D	logFF4D	logFF4C	FF5	FF6
	M							X	X		X	X
1	L		X	X	X	X[X]			[X]	X		
	nil	X		[X]			X					
	M							X	X		X	X
2	L		X	X	X	X[X]			[X]	X		
	nil	X		[X]			X					
	H			X				X	X		X	X
3	M				X	X						
	L		X			[X][a]	X		[X][a]	X		
	nil	X		[X]		[X][b]			[X][b]			
	H							X			X	X
4	M									X		
	L		X	X	X	X[X]	X		X[X]			
	nil	X		[X]								
5	nil	X	X	X	X	X	X	X	X	X	X	X

[a] Hack-and-squirt without foliar underspray.
[b] Hack-and-squirt with foliar underspray.
[c] Season 4 ratings for all seral stages are higher when patches of this type are beside spawning channels used by bears.
[d] Nat=naturally occurring successional stage, log=post-logging succession.

Non-commercial habitat types (no seral stages):

Season	Rating	AV	ES	RO	RT	SF	WE
	H		X				X
1	M					X	
	L	X					
	nil			X	X		
	H	X	X				X
2	M					X	
	nil			X	X		
	H		X				
3	M	X				X	X
	nil			X	X		
4	M		X				
	L	X				X	X
	nil			X	X		
5	H					X	
	nil	X	X	X	X		X

APPENDIX 4. Site history information for sampled blocks

Block	Logged	Site preparation	Planted	Site treatments	Comments
CK01	no				Hack-and-squirt control
CK02	1965	Poss. burn 1965	1971	1988 hack-and-squirt *and girdling*	
CK03	1973	Burn 1974	1975	1987 aerial (heli.) 1.78 g a.i./ha	High herbicide impacts
CK04	1973		1975	1987 hack-and-squirt 1.01 g a.i./ha with foliar underspray	
CK05	1972		1973	1987 hack-and-squirt 1.01 g a.i./ha with foliar underspray	
CK06	1974		1976	1988 hack-and-squirt	
CK07	1984		1985	1987 aerial (heli.) 1.78 g a.i./ha	V. high herbicide impacts
CK08	1978		1981 1985–6	1985 chemical, also 1987?	Flooded in fall 1988
CK09	1979		1980 1981?	1984 mech. and chemical	
P01	1984–5	Burn 1986	1987	1988 aerial (& powerhose?)	Mod. to high herbicide impacts, patchy treatment
P02	1986		1988	1988 ground foliar	High herbicide impacts
P03	1979 (1976?)		?	1988 hack-and-squirt and backpack	Patchy treatment
P04	1985–6	To be burned	To be fill planted	1988 aerial	High to v. high herbicide impacts
P05	1984		?	1987 ground foliar	High herbicide impacts, patchy treatment
P06	1981		1982?	1987 ground foliar	Mod. to high herbicide impacts
P07	1984	Burn 1985	1986	1986 ground foliar	
P08	1981?		1981?	1986? ground foliar	
KG02	1984–5		1987	1988 backpack	High herbicide impacts
KG03	1981		1984 1989	1988 hack-and-squirt with foliar underspray, site prep. for planting	Mod. herbicide impacts, patchy treatment
KG04	1975		1976 1989?	1988 hack-and-squirt with foliar underspray, site prep. for planting	
KG05	1986		1987?	1988 backpack	Mod. to high herbicide impacts, patchy treatment
KN01–5	1978–9		1979	1983 mech. brush & weed, 1988 aerial (heli.)	Rates: KN01 – 0.71 kg a.i./ha KN02 – control KN03 – 0.36 kg a.i./ha KN04 – 1.42 kg a.i./ha KN05 – control

APPENDIX 5. Site and soil characteristics of macroplots sampled in 1988 and 1989

Blk	Plot	Slope pos.	Aspect	% Slope	Moisture regime	Nutrient regime	Expos.	Seral stage	Soil	Humus[a]	Soil texture
KN01	T01	level	999	0	subhygric	permesotrophic	na	C	CU.R	HR	Si,FS
KN01	T02	level	999	0	subhygric	permesotrophic	na	C	CU.R	HR	Si-MS
KN01	T03	level	999	0	subhygric	permesotrophic	na	C	R.G	HR	SiS-MS
KN02	C01	level	999	0	subhygric	permesotrophic	na	C	CU.R	HR	Si-CS
KN02	C02	level	999	0	subhygric	permesotrophic	na	C	R.G	HR	SSi-MS
KN02	C03	level	999	0	subhygric	permesotrophic	na	C	R.G	HUR	Si-MS
KN03	T01	level	999	0	subhygric	permesotrophic	na	C	CU.R	WR	SSi-MS
KN03	T02	level	999	0	subhygric	permesotrophic	na	C	CU.R	WR	FS,MS
KN03	T03	level	999	0	subhygric	permesotrophic	na	C	CU.R	WR	FS,MS
KN04	T01	level	999	0	subhygric	permesotrophic	na	C	CU.R	WR	SiS-MS
KN04	T02	level	999	0	subhygric	permesotrophic	na	C	CU.R	WR	FS,MS
KN04	T03	level	999	0	subhygric	permesotrophic	na	C	CU.R	WR	FS,MS
KN05	C01	level	999	0	subhygric	permesotrophic	na	C	CU.R	WR	Si-MS
KG02	T01	mid	266	na	mesic	permesotrophic	na	C	O.FHP	HUR	LS
KG02	T02	toe	286	na	mesic	permesotrophic	na	C	O.R	D	CS
KG03	T01	level	999	0	mesic	permesotrophic	na	C	CU.R	WR	SiS-MS
KG03	T02	level	999	0	mesic	permesotrophic	na	C	CU.R	na	SiS-MS
KG04	T01	level	999	0	mesic	permesotrophic	na	D	CU.R	WD	SiS-CS
KG04	T02	level	999	0	mesic	permesotrophic	na	D	CU.R	WD	SSi-CS
KG04	C03	level	999	0	mesic	permesotrophic	na	D	CU.R	WD	SSi-CS
KG05	T01	level	999	0	hygric	permesotrophic	na	C	GL.R	na	FS,MS
KG05	T02	level	999	0	hygric	permesotrophic	na	C	GL.R	WD	SiS-MS
KG05	C03	level	999	0	subhygric	permesotrophic	na	C	CU.R	WD	SiS,FS
CK01	C01	level	999	0	subhygric	permesotrophic	na	E	CU.R	WD	FS,MS
CK02	T01	level	999	0	subhygric	permesotrophic	na?	D	CU.R	WD	FS,MS
CK02	T02	level	999	0	subhygric	permesotrophic	na?	D	CU.R	WD	FS,CS
CK02	T03	level	999	0	subhygric	permesotrophic	na?	D	CU.R	TD	LS,CS
CK02	T04	toe	10	3	subhygric	permesotrophic	na?	D	CU.R	TD	LS,CS
CK02	T05	toe	340	5	subhygric	permesotrophic	na?	D	CU.R	TD	L,CS
CK02	T06	toe	352	7	subhygric	permesotrophic	na?	D	CU.R	TD	FS,CS
CK03	T01	mid	262	15	mesic	permesotrophic	cold	D	O.FHP	UR	SL,LS
CK03	T02	mid	262	10	mesic	mesotrophic	cold	D	O.R	UR	FS-CS
CK04	T01	level	999	0	subhygric	permesotrophic	na	D	CU.R	WD	SiS,FS
CK04	T01	level	999	0	subhygric	permesotrophic	na	D	CU.R	WD	FS
CK05	T01	level	999	0	subhygric	permesotrophic	na	D	CU.R	TD	FS,CS
CK05	T02	level	999	0	subhygric	permesotrophic	na	D	CU.R	TD	MS,CS
CK06	T01	level	999	0	subhygric	permesotrophic	na	D	CU.R	UR	MS,CS
CK06	T02	level	999	0	subhygric	permesotrophic	na	DE	CU.R	WD	FS,CS
CK06	T03	level	999	0	hygric	permesotrophic	na	D	CU.R	WD	SiS,MS
CK07	T01	level	999	0	subhygric	permesotrophic	na	C	CU.R	HR	MS,CS
CK07	T02	level	999	0	subhygric	permesotrophic	na	C	CU.R	HR	FS,MS,LS
CK08	T01	level	999	0	subhygric	permesotrophic	cold	C	CU.R	na	FS,MS
CK08	T02	level	999	0	subhygric	permesotrophic	cold	C	CU.R	na	FS-CS
CK09	T01	level	999	0	subhygric	permesotrophic	na	D	CU.R	WD	FS,CS
CK09	T02	level	999	0	subhygric	permesotrophic	na	C	CU.R	HUR	SSi-CS
P01	T01	level	999	0	mesic	permesotrophic	na	C	O.HFP	TD	FS-CS
P01	T02	level	999	0	subhygric	permesotrophic	na	C	CU.R	TD	FS-CS

APPENDIX 5. (Continued)

Blk	Plot	Slope pos.	Aspect	% Slope	Moisture regime	Nutrient regime	Expos.	Seral stage	Soil	Humus[a]	Soil texture
P01	T03	level	999	0	subhygric	permesotrophic	na	C	O.HFP	TD	FS-CS
P01	T04	level	999	0	subhygric	permesotrophic	na	C	CU.R	HUR	FS-CS
P01	T05	level	999	0	subhygric	permesotrophic	na	C	CU.R	WR	FS,MS
P01	T06	level	999	0	subhygric	permesotrophic	na	C	CU.R	TD	MS,CS
P02	T01	level	999	0	subhygric	permesotrophic	na	C	O.DYB	TD	FS,MS
P02	T02	level	999	0	subhygric	permesotrophic	na	C	O.DYB	TD	FS,MS
P02	T03	level	999	0	subhygric	permesotrophic	na	C	O.R	RD	FS-CS
P02	T04	level	999	0	subhygric	permesotrophic	na	C	O.R	WD	FS-CS
P02	T05	level	999	0	subhygric	permesotrophic	na	C	CU.R	HR	Si,FS,MS
P02	C06	level	999	0	subhygric	permesotrophic	na	C	O.R	TD	FS,CS
P03	C04	level	999	0	hygric	permesotrophic	cold	D	wet	na	wet
P03	T05	level	999	0	subhygric	permesotrophic	na	D	wet	na	wet
P03	T06	lower	160	25	subhygric	permesotrophic	na	D	O.R	UR	CS,LS
P04	T01	toe	100	8	subhygric	permesotrophic	na	C	O.DYB	TD	LS
P04	T02	level	999	0	subhygric	permesotrophic	na	C	O.FHP	RD	SL
P04	T03	level	999	0	subhygric	permesotrophic	na	C	O.DYB	TD	SiL
P04	T04	level	999	0	subhygric	permesotrophic	na	C	O.FHP	TD	colluvium
P04	T05	level	999	0	subhygric	permesotrophic	na	C	podzol?	UR	MS?
P04	T06	level	999	0	subhygric	permesotrophic	na	C	podzol?	UR	MS
P05	T01	level	999	0	subhygric	permesotrophic	cold	C	podzol?	na	CS
P05	T02	level	999	0	subhygric	permesotrophic	cold	C	O.R	UR	LS,CS
P06	T01	level	999	0	subhygric	permesotrophic	cold	C	O.HFP	UR	SL-LS,MS
P06	T02	level	999	0	subhygric	permesotrophic	cold	C	GL.R	TD	Si,MS
P07	T01	mid	90	23	subhygric	permesotrophic	cold	C	O.HFP	HR	L
P07	T02	mid	90	21	mesic	mesotrophic	cold	C	O.HFP	HR?	SL
P08	T01	level	999	0	subhygric	permesotrophic	na	C	O.R	HR	MS,CS
P08	T02	level	999	0	subhygric	permesotrophic	na	C	CU.R	UR	FS,CS

[a] Abbreviations from Walmsley *et al.* (1980).

APPENDIX 6. Change in percent cover between 1988 and 1989 for plant species other than fruit-producing shrubs with cover ≥1% in at least 1 year, summarized by treatment type. (I=increase >1%, D=decrease >1%, C=constant - change ≤1%, N=new occurrence, L=lost). Underlining indicates coastal grizzly bear forage species other than fruit-producing shrubs (Hamilton 1987).

	1988 foliar							1987 foliar				1984–6 foliar		
	KG02	KG05	P01	P02	P04	KG03	P03	P05	P06	CK03	CK07	P07	P08	CK09[2]
AGROSTI								N?						L
ATHYFIL	L	D	D	D	L	D			I				C	I
BLECSPI			C				D			I				
CALACAN														
CARECAN						C								
CIRCALP	D		D		D			I			I			D
CLINUNI			I						I					
CORNCAN			C		D				I	I		C		
CYSTFRA		D												
DICEFOR				I										
DISPHOO						L								
DRYOASS	D		D	D	D					I		I	D	
EPILANG	I	I	C	D	D	D	D	I	I	I	C	I	I	I
EPILGLA		I				N		I			I		D	
EQUIARV														
FESTSUB						D			I				D	
GALITRF		I		C		I			I				I	D
GYMNDRY	D		C					C						
HERASPH														
LYSIAME		I												
MAIADIL				C				I	I				I	
MENZFER			C										I	
MIMULEW		D												
MYCEMUR								I				C		
POLYBRA											C			
POPUBAL														I
RUBUPED			D		D			I	I					
SMILSTE				I										
SONCHUS						I								
STACCOO					C								C	
STELCRI				C						I				
STREAMP														C
STREROS								I						
TELLGRA											I			
TIARTRI	D	I	D	D	D	D		I	C	I	I			
TIARUNI	L													
TOLMMEN		I		D										
TRAUCAR		I	I	I		I	I				D		I	D
TRISCER										N			C	
VALESIT														
VIOLGLA									I					

APPENDIX 6. (Continued)

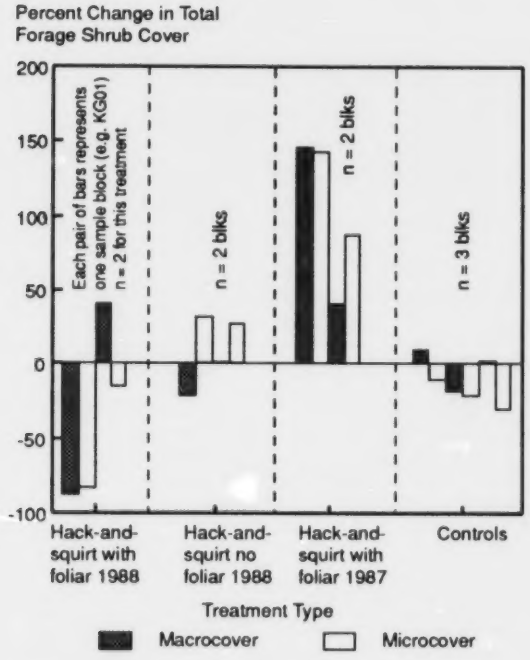
	1988 hack-and-squirt with foliar[a]		1988 hack-and-squirt no foliar		1987 hack-and-squirt with foliar		Foliar controls		Hack-and-squirt controls		
	P03	KG04	CK02[b]	CK06	CK04	CK05	KG05	P02	P03	KG04	CK01
ACTAARG								N			
AGROSTI					N						
ALNURUB		D	L	L							
ARUNDIO					I						
ATHYFIL				C	I	I	D	I	C		D
CAREMER		N									
CINNLAT		N									
CIRCALP		I			C						
CLAYSIB						I					
DICEFOR			I								
DRYOASS	D		I	N		D		C	C	C	
EPILANG				D				I			
EPILGLA		N									
EQUIARV					C						
GALIKAM						I					
GALITRF		I									
GYMNDRY				C						C	
LYSIAME	D								D		
MAIADIL			C					C		I	
POLYBRA			C								
POLYMUN										I	
RUBUPED									C		
SONCHUS		N									
STREROS				I	C						
TIARTRI	I			I	C	I		I		I	
TOLMMEN					I	C					I
TRAUCAR		I	I	I	D	D		I		I	D

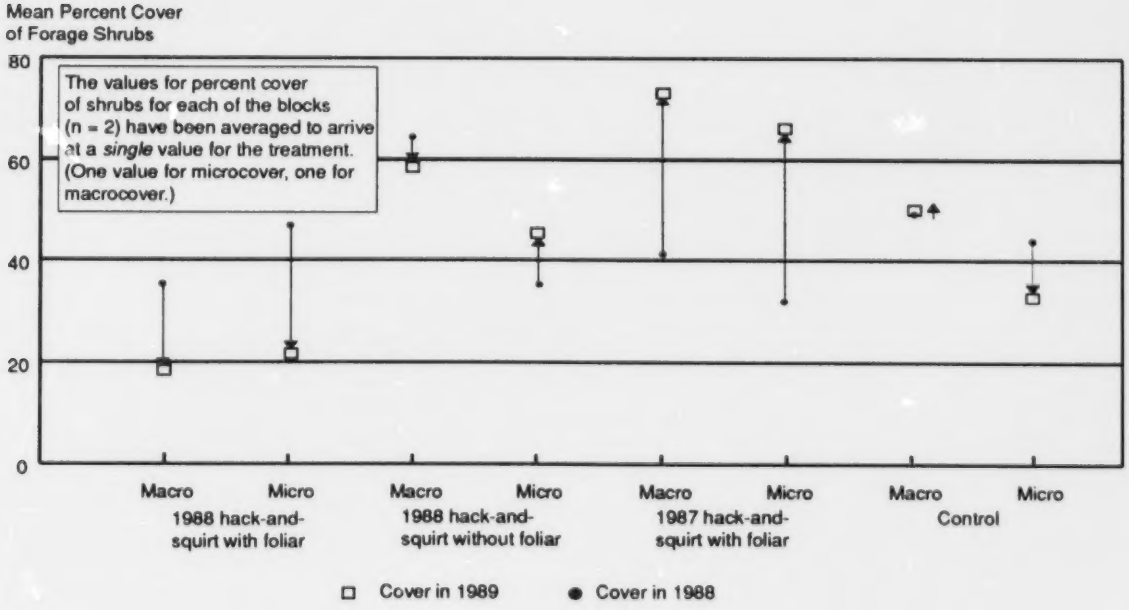
[a] Combined herbicide and mechanical treatment in 1984.
[b] Some large shrubs cut down.

APPENDIX 7. Change in percent cover between 1988 and 1989 for plant species other than fruit-producing shrubs with cover ≥1% in at least 1 year, summarized by glyphosate application rate. (I=increase >1%, D=decrease >1%, C=constant - change ≤1%, N=new occurrence, L=lost). Underlining indicates coastal grizzly bear forage species other than fruit-producing shrubs (Hamilton 1987).

	0.36 kg a.i./ha	0.71 kg a.i./ha	1.42 kg a.i./ha	Control 1	Control 2
ALNURUB				I	
ATHYFIL		D	L	D	
CALAMAG				I	
CARECAN		I		D	
CINNLAT	L	I		D	N
DISPHOO			L		
ELYMGLA	I	D	I	I	I
EPILANG	D	D	D	D	D
EQUIARV		I		D	
FESTRUB	I				
FESTSUB	I	C	D		
FRAGVES				N	
FRAGVIR				L	
GALITRF		I	I	D	C
GEUMMAC	I	D	I		
GYMNDRY	D	I	D	D	
LUZUSPI	L				
ORTHSEC		D			
POA	I		I		I
POPUBAL		D			D
ROSANUT		D		D	
SALISIT					D
STELLAR		I			
TARAOFF	C		I		C
TIARTRI		D		D	
TIARUNI			D	D	
TRISCER	D	I	I		

APPENDIX 8. Graphing conventions




Mean Percent Cover
of Forage Shrubs
80
60
40
20
0
The values for percent cover of shrubs for each of the blocks (n = 2) have been averaged to arrive at a *single* value for the treatment. (One value for microcover, one for macrocover.)
Macro
Micro
1988 hack-and-squirt with foliar
1988 hack-and-squirt without foliar
1987 hack-and-squirt with foliar
Control
Cover in 1989
Cover in 1988